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ABSTRACT

This document contains the proceedings of the 2001 Annual International Conference of the Association for the Education of Teachers in Science which was held in Costa Mesa, California, January 18-21, 2001. Papers include: (1) "An Elementary Preservice Teacher's Search for Solutions about the Evolution-Divine Creation Question: The Story of Tracy" (Larry D. Yore and Tracey Knopp); (2) "Stars: Evaluating the Use of Video Technology for Modelling Science Process Skills" (Kenneth P. King and Thomas E. Thompson); (3) "Site-Based Professional Development: Learning Cycle and Technology Integration" (Brian L. Gerber, Andrew J. Brovey, and Catherine B. Price); (4) "Professional Development as Inquiry: The Role of Formative Assessment in Professional Development" (Doris Ash, Karen Levitt, and Lin Tucker); (5) "A Comparative Analysis of Science Teacher Education in Global Communities" (Pamela Fraser-Abder); (6) "Infusing Technology to Enhance Science Lessons: Prospective Teachers as Action Researchers Learning to Teach for Conceptual Change" (M. Randall Spaid); (7) "Professional Development for Elementary School Teachers Working with Science Learning Outcomes" (Ken Appleton and Allan Harrison); (8) "Views of Nature of Science Questionnaire (VNOS): Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science (Fouad Abd-El-Khalick, Norm G. Lederman, Randy L. Bell, and Renee S. Schwartz); (9) "Thinking Reflectively Rather Than Reflexively: A Theoretical Framework for Portfolio Development in Teacher Education" (Christopher Andersen); (10) "Prospective Elementary Teachers' Use of an Online Communicative Tool: Implications for the Use of Technology in Science Teaching Preparation" (Lucy Avraamidou and Barbara Crawford); (11) "Inquiry-Based Research Published in 'I Wonder': The Journal for Elementary School Scientists (1999-2000)" (Michael E. Beeth and Tracy Huziak); (12) "Pre-Service Science and Mathematics Teachers as Cultural Agents: A Transformative Study" (Carolyn Butcher and Gilbert Valadez); (13) "Increased Science Achievement for Adolescent Girls" (Nancy Stubbs and Caryn Hoffman);

(14) "What Do We Know about Students' Cognitive Conflict in the Science Classroom: A Theoretical Model of Cognitive Conflict Process" (Gyoungho Lee and Jaesool Kwon); (15) "Science and Language Links" (Zale A. Liu and Valarie L. Akerson); (16) "Learning Science through Reading: Fifth-Grade Students' Conceptualization of Observation and Inference" (Francis S. Broadway and Katherine Taillon); (17) "Does Being Wrong Make Kettlewell Wrong for Science Teaching?" (David Wyss Rudge); (18) "Integrating Technology into Teacher Preparation and K-12 Classrooms" (Vickie D. Harry and R. Elaine Carbone); (19) "Technology: Preservice Teachers' Preparation: Oil: Water" (Patricia D. Morrell and James B. Carroll); (20) "Using Electronic Classrooms and the World Wide Web to Support Science Teaching and Learning: Interactive Session Summary" (Paul Vellom, Marcia Fetters, and Michael Beeth); (21) "The Philosophy, Theory and Practice of Science-Technology-Society Orientations" (Chris Lawrence, Robert Yager, Scott Sowell, Elizabeth Hancock, Yalcin Yalaki, and Paul Jablon); (22) "Eighth-Grade African American Students' Sense-Making of Electricity" (Morgan C. Greene and Francis S. Broadway); (23) "Making Science Accessible: Strategies for Modifying Science Activities to Meet the Needs of a Diverse Student Population" (Marcia Fetters, Dawn Pickard, and Eric Pyle); (24) "An Environmental Education Needs Assessment of K-12 Teachers" (Yvonne Meichtry); (25) "Language Development and Science Inquiry: A Child-Initiated and Teacher-Facilitated Program" (Evelyn P. Klein, Penny L. Hammrich, Stephanie Bloom, and Anika Ragins); (26) "Examining Discourse in Elementary Science Methods: Differences between Science Content and Pedagogy" (William J. Newman, Jr., Paula D. Hubbard, and Sandra K. Abell); (27) "Science Work Experience Programs for Teachers: Refocusing Professional Development Using a Qualitative Lens" (Wendy M. Frazier); (28) "An Extension Analysis on the Self-Efficacy Beliefs about Equitable Science Teaching and Learning Instrument for Prospective Elementary Teachers" (Jennifer M. Ritter, William J. Boone, and Peter A. Rubba); (29) "Impact of Global School/University Partnerships on Science Teacher Enhancement" (Jack Hassard and Julie Weisberg); (30) "Learning Together: A Collaboration between Researcher and Classroom Teacher Using Inquiry-Based Instruction" (James T. McDonald); (31) "What Is Necessary to Include in a Science Methods Course for Teachers on Emergency Permits?-- The Role of the Feedback Portfolio" (Hedy Moscovici); (32) "Jumping onto the Portfolio Bandwagon: What Teachers Say about the Process" (Mary Stein); (33) "The Sisters in Science Program: A Three Year Analysis" (Penny L. Hammrich, Greer Richardson, and Beverly Livingston); (34) "Team: Staff Development and Mentoring for Urban Elementary Teachers, Preservice Teachers, and Students" (Kenneth King and Thomas Thompson); (35) "Science as a Way of Knowing: Using Reader Response as a Means to Construct a Personal Understanding of Science Literature" (Robert W. Blake, Jr. and Robert W. Blake); (36) "Getting to the Fourth Year" (Patricia R. Simpson, George Davis, Teresa Shume, David Cline, and Dorrie Tonnis); (37) "Profile Changes for Two Students in a (Mathematics, Science and Technology Education) Preservice Teacher Education Program with Constructivist Views of Teaching and Learning" (Youngsun Kwak and Michael E. Beeth); (38) "Sharing Our Strategies: A Role for Science Teachers" (Pamela Fraser-Abder and Nina Leonhardt); (39) "Sisters in Science: Using Sports as a Vehicle for Science Learning" (Penny L. Hammrich, Greer M. Richardson, Tina Sloan Green, and Beverly Livingston); (40) "Strategies Enabling Collaborative Teacher Teams to Develop and Implement Assessment of Student Understanding of Science" (Donna R. Sterling); (41) "The Bridges Project: Pairing Preservice and Inservice Teachers for Professional Development in Science, Math, and Literacy Using Performance Assessment Tasks as Contexts" (Valerie L. Akerson, Amy McDuffie, and Judith A. Morrison); (42) "Elementary Science Teacher Leadership (ESTL) Program: A Professional Development Model" (Marlene Thier and Herbert Thier); (43) "Secondary Science Teacher Candidates' Beliefs and Practices" (Deborah

Waggett); (44) "Awakening the Scientist Inside: Global Climate Change and the Nature of Science in an Elementary Science Methods Course" (Juanita Jo Matkins and Randy Bell); (45) "Changes in the Philosophies of Teaching of Four Interns during the Internship Year" (Michael J. Wavering); (46) "From Practice to Theory--Narrowing The Gap: First Year Teachers Emerging from a Constructivist Science Education Program" (Michael Dias and Jack Hassard); (47) "Reconceptualizing a General Chemistry Curriculum Using a Standards-Based Approach to Instruction" (Warren J. DiBiase and Eugene P. Wagner); (48) "Documenting Strategies for Two Local Systematic Change Projects" (Larry D. Yore, James A. Shymansky, and John O. Anderson); (49) "Constructing Investigations: Collaborative Professional Development in Technology and Science Education" (Lawrence B. Flick, Walter Gamble, and Dick O'Connor); (50) University Science Majors in Collaborative Partnerships with Elementary Teachers: Inquiry Based Teaching and Learning" (Donna L. Ross and Cheryl L. Mason); (51) "The Relationship between Attitude toward Science and Enrollment in a 4x4 Block Schedule" (James E. Spellman and J. Steve Oliver); (52) "A Revised Introductory-Level College Science Course: Steps Toward an Inclusive Pedagogy" (Tarin H. Weiss); (53) Daughters with Disabilities: A Professional Development Model to Reframe Science, Math, and Technology Education for Girls with Disabilities" (Penny L. Hammrich, Lynda Price, and Graciela Slesaransky-Poe); (54) "The Levels of Accessibility Matrix System for Determining the Appropriateness of Hands-On Science Activities for Students with Disabilities" (E. Barbara Klemm and Joseph R. Laszlo); (55) "The Effects of an After-School Science Program on Middle School Female Students' Attitudes toward Science, Mathematics and Engineering" (Maria M. Ferreira); (56) "Science and Mathematics Professional Development at a Liberal Arts University: Effects on Content Knowledge, Teacher Confidence and Strategies, and Student Achievement" (Cynthia H. Greer); (57) "Sexuality Has a Place in the Science Classroom" (Anne-Marie Scholer); (58) "Drawing on Their Understanding: Using Illustrations to Invoke Deeper Thinking about Plants" (Shannan McNair and Mary Stein); (59) "Block Scheduling Science: Does It Help or Hinder?" (Donna L. Ross and Julie F. Westerlund); (60) "'Just in Time': An Alternative Pathway to Teaching (APT)" (Camille L. Wainwright); (61) "Issues in the Preparation of Teachers to Face the Challenge of the Black-White Achievement Gap in Science: 'I Love Your Questions, But We Have to Get Through This Stuff'" (Charles R. Ault, Jr. and Obed Norman); (62) "Stories From the Field: Challenges of Science Teaching and Learning through Interdisciplinary Approaches" (Katherine C. Wieseman, Hedy Moscovici, Turtle Moore, Jill van Tiel, and Esme McCarthy); (63) "The Genesis of Science Teaching in the Elementary School: The Influence of Student Teaching" (Lee A. Plourde); (64) "Goals 2000 and Action Research: A Viable Plan for Teachers" (David T. Crowther, Norman G. Lederman, Bob Curtis, and John R. Cannon); (65) "Three Non-Western European Student Teachers' Conceptions of Teaching Science to Adolescent English Language Learners" (J. Richard Pomeroy); (66) "Calibrated Peer Review in General Education Undergraduate Human Physiology" (Nancy J. Pelaez); (67) "The Space Exploration Team Inquiry Model: Linking NASA to Urban Education Initiatives" (Richard E. Shope III and Lloyd Chapman); (68) "Improving University Science and Engineering Instruction--A Case Study of an Environmental Engineering Lab Course" (Valarie L. Akerson, Victor F. Medina, and Nina Wang); (69) "Creating an Integrated Elementary Teacher Education Program: The Response of Nine California State University Campuses" (Laura Henriques, Amy Cox-Peterson, Bonnie Brunkhorst, Herb Brunkhorst, Barbara Burke, Alan Colburn, Teresa Crawford, Barbara Gonzalez, Barbara Hawkins, Cheryl L. Mason, John McGowan, Hedy Moscovici, Kathy Norman, Nancy Pelaez, Donna L. Ross, Gerry Simila, Ed Walton, and Robert Yamashita); (70) "Technology: A Link to the Mountains and Beyond, Discourse Practices in a Web Course for Elementary Science Teachers" (Kathleen S. Davis); and (71)

"The Impact of Constructivist Instructional Methods on Preservice Teachers' Attitudes toward Teaching and Learning Science (Helen L. Gibson, James Bernhard, Aaron Kropf, and Georgena A. Van Strat). (YDS)

ED 453 083

Proceedings of the 2001 Annual International Conference of the Association for the Education of Teachers in Science

Edited by:

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Warren J. Di Biase, University of North Carolina at Charlotte
Barbara A. Crawford, The Pennsylvania State University

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Preface

These are the proceedings of the 2001 Annual International Conference of the Association for the Education of Teachers in Science, held in Costa Mesa, CA, January 18-21, 2001. It is the sixth in the set of proceedings of AETS annual conferences. Over 70 papers and summaries of presentations from the conference are included, ordered by the corresponding conference session designation and by the first author's last name if it did not appear in the printed conference program. The conference program also is included.

Each paper and presentation summary submitted for inclusion in the proceedings was reviewed by one of the four editors. Because these proceedings are to serve as a record of the 2001 AETS annual meeting, the papers and presentation summaries were not heavily edited and were not refereed. Those papers and presentation summaries that were revised and returned by a designated date were included.

These proceedings are disseminated via the ERIC Clearinghouse for Science, Mathematics and Environmental Education in microfiche form (with hard copy available through ERIC) and on the AETS World Wide Web Site at URL http://www.aets.unr.edu/. Given ERIC documents and web materials are not copyrighted, papers and presentation summaries included in these proceedings may be submitted for publications in journals such as the *Journal of Science Teacher Education* and *Science Education.* For information on how to secure a microfiche or hard copy of these proceedings through ERIC, see your campus or local library, WWW URL http://edrs.com/, or phone 800-433-ERIC. Also, the papers and presentation summaries included in these proceedings may be downloaded directly from the AETS WWW site as a RTF (Rich Text Format) file.

We are very pleased to have had the opportunity to edit these proceedings.

Peter A. Rubba, The Pennsylvania State University
James A. Rye, West Virginia University
Warren J. Di Biase, University of North Carolina at Charlotte
Barbara A. Crawford, The Pennsylvania State University

Acknowledgment

The editors gratefully acknowledge the assistance of Nancy J. Thomas in helping to compile these proceedings and Bobbi Robison for placing them on the Web.

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Association for the Education of Teachers in Science, 2001 Annual International Conference, January 18-21, 2001: Costa Mesa, CA.

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California State University, San Marcos, College of Education

Conference Theme: 2001 and Beyond: New Horizons in Science Teacher Education

Welcome to the 2001 AETS International Conference in Southern California. The Westin-South Coast Plaza is in Costa Mesa, three miles from the John Wayne/Orange County Airport. The Westin is a luxurious hotel that adjoins South Coast Plaza, a unique retail center featuring more than 275 premier shopping and dining choices. Nearby are Balboa Island, Newport Beach, Laguna Beach, Disneyland, Knott's Berry Farm, Catalina Island, Dana Point, the Orange County Performing Arts Center, South Coast Repertory Theatre, and several art museums.

The Conference Theme is 2001 and Beyond: New Horizons in Science Teacher Education. This AETS Conference will be a joint meeting with the 5th Annual Conference of the Association of Mathematics Teacher Educators (AMTE). Preconference workshops and tours will be held Thursday morning, and concurrent sessions will begin at 1 p.m. on Thursday. Keynote sessions will be held Thursday and Friday afternoons. The opening reception will be Thursday after the Keynote address. Optional evening events for Friday and Saturday include a trip to the J.P. Getty Museum in Los Angeles, and a Cabaret at the Orange County Performing Arts Center.

Dr. Richard Villa and Dr. Jacqueline Thousand, international speakers/authors on inclusive education will present the Thursday keynote. Dr. Villa and Dr. Thousand have authored numerous books, research articles and book chapters on practical how-to strategies for meeting the needs of all students in general education; adapting curriculum, instruction, and assessment; collaborative teaming; co-teaching; and creative problem-solving. Both have extensive experience working with educational opportunities for students with various disabilities and/or who are at-risk for school failure. Their keynote will address characteristics of successful inclusionary schools; implementation of recent legislative mandates; and implications for science teacher preparation.

Dr. Stewart Sumida and Dr. Elizabeth Rega will be the keynote speakers for the general session on Friday. They will discuss the use of media to illustrate science content in teacher education settings. Dr. Stuart Sumida is a specialist on the evolution of back-boned animals, and is consultant on various Disney films including Beauty and the Beast, Lion King, Pocahontas, Hercules, Mulan, Tarzan, and the upcoming Dinosaur and Fantasia 2000. Dr. Sumida's work in vertebrate paleontology has been featured in National Geographic. Dr. Elizabeth Rega has become the world's first choice for translating elements of human and primate anatomy to artists. She has worked on Pocahontas, Tarzan, Mulan Prince of Egypt, and Dinosaur.

Corporate sponsors for 2001 AETS are Delta Education, Casio, Inc., Texas Instruments, Biological Sciences Curriculum Study, California State University, San Marcos College of Education and the Institute for Science Education, California State University, San Bernardino. Exhibitors include NASA, Join Hands Educational Foundation, ESRI Schools and Libraries and The University of Texas at Austin Science Education Center. As a member of AETS and a conference attendee, please let these organizations know how much you appreciate their support of AETS. We would like to thank all the committee members listed on the following page. We would like to thank John Cannon, our Director of Electronic Service for making all conference information and registration forms available through the AETS Web site and the listserve. We wish to thank Jon Pederson for leading the registration process and for providing for fiscal arrangements. Additional thanks are given to previous AETS conference committees, whose members provided ideas and advice on various aspects of carrying out an AETS conference.

We hope that you will enjoy Costa Mesa and our 2001 AETS Conference. If you have questions, concerns, or comments please let us know.

Kathy Norman and James Barufaldi, Conference Co-chairs

AETS 2001 Conference Committee

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AETS 2001 CONFERENCE SCHEDULE

January 18-21, 2001
The Westin – South Coast Plaza
Costa Mesa, California

Wednesday

6:00 p.m. – 10:00 p.m.	AETS Board Meeting
7:00 p.m. – 9:00 p.m.	Registration

Thursday

7:00 a.m – 5:00 p.m.	Registration
8:30 a.m. – 12:00 noon.	Pre-conference Workshops and Tours
1:00 p.m. – 3:20 p.m.	Concurrent Sessions
3:20 p.m. – 4:00 p.m.	Coffee Break
4:00 p.m – 5:15 p.m.	General Session and Keynote Address
5:15 p.m. – 7:15 p.m.	Reception and Poster Session

Friday

6:30 a.m. – 8:00 a.m.	Continental Breakfast with AMTE
7:00 a.m. – 5:00 p.m.	Registration
8:00 a.m. – 11:40 a.m.	Concurrent Sessions
11:45 a.m. – 1:15 p.m.	Lunch and Committee Meetings
1:20 p.m. – 2:20 p.m.	Concurrent Sessions
2:20 p.m. – 2:40 p.m.	Coffee Break with AMTE
2:40 p.m. – 3:40 p.m.	Concurrent Sessions
3:45 p.m. – 5:00 p.m.	General Session and Keynote Address
5:00 p.m. – 10:00 p.m.	Trip to J.P. Getty Museum (bus leaves at 5:10) (Tickets must be purchased prior to event)

Saturday

6:30 a.m. – 8:00 a.m.	Continental Breakfast with AMTE
7:00 a.m. – 5:00 p.m.	Registration
8:00 a.m. – 11:40 a.m.	Concurrent Sessions
12:00 noon– 2:00 p.m.	Awards Luncheon and Business Meeting
2:15 p.m. – 5:55 p.m.	Concurrent Sessions
7:30 p.m. – 9:30 p.m.	Women in Science Education Dessert Function (Tickets must be purchased prior to event)

Sunday

6:30 a.m. – 8:00 a.m.	Continental Breakfast
8:00 a.m. – 12:00 noon	AETS Board Meeting
8:00 a.m. – 10:20 a.m.	Concurrent Sessions

THE AETS TIME CAPSULE

This year's AETS Conference begins a time odyssey that culminates in the AETS Centennial Anniversary in the year 2030. The 2001 Conference Committee has purchased a top grade, stainless steel, certified time capsule for our messages to the future. Write your message to science educators of the future on the back of your business card (or attach to your business card). Turn in your message and business card at the Registration desk along with other items that will be beneficial to future science educators. The messages and selected items will be placed in the AETS Time Capsule. The Capsule will be opened at the 2030 AETS Conference, but before sealing it in 2001, we will share a few of the messages with you.

AETS 2001 Pre-Conference Workshops

8:30 – 12:00 noon - January 18, 2001

Workshop 1 – Integrating Nature Legends Across the Curriculum **San Diego**
This session will present storytelling as a method of using legends to convey science topics and concepts. The session will use lecture, storytelling, cooperative groups, and writing to convey concepts. Participants will hear stories and be able to write their own nature legend. Presenter: Candace R. Miller

Workshop 2 – Problem-based Learning (PBL) and Science Instruction **San Pedro**
This session will provide an overview of Problem-Based Learning, including PBL as an instructional strategy, the nature of ill-structured problems, the flow of activity during problem-based units, and assessment of learning during PBL. Presenters: Warren DiBiase and William Stepien

Workshop 3 – Building Web-Based Portfolios to Support Learning to Teach **San Marcos**
This practical, hands-on workshop will feature opportunities to (1) explore web-based science teaching portfolios prepared by perspective science teachers, (2) develop basic hypermedia and website construction techniques, and (3) learn about policies and procedures that can facilitate a teacher education web-based portfolio program. Presenters: Tom Dana, Carla Zemal-Saul, Leigh Boardman, and Kathleen Sillman.

Workshop 4 – Moving from 'They should…' to 'I will…' **San Juan**
The Role of Field Experience in Becoming a Teacher
This session focuses on the role of field experiences and entry-year support programs at two universities in shaping and supporting your professionals' inquiry-based practices. The basic structures, expectations, and evaluation tools will be presented, and participants will select and work collectively on a number of critical issues, such as inclusion, multi-cultural approaches, high stakes testing, structuring safe laboratories, educational technologies, and authentic assessment. Presenters: Paul Vellom and Marci Fetters

Workshop 5 – Creating a Classroom Community of Young Scientists **San Felipe**
This workshop will explore, develop and expand key concepts, themes, and strategies in elementary science teacher education (re: Creating a Classroom Community of Young Scientists: A Desktop Companion by Jeff Bloom). Key concepts to be developed include (a) responding to children's thinking and ideas in science (b) developing understanding of inquiry in science and learning; (c) developing philosophical and theoretical frameworks of science teaching; and (d) developing communities in the classroom and beyond. Presenters: Jeff Bloom and Vince Lunetta

Workshop 6 – A Working Micro-Conference on Urban Science Teaching **San Carlos**
This session will serve as a catalyst for sharing expertise and fashioning connections among individuals interested in urban science teaching. Participants will communicate their responses to these issues: reaching consensus about uniqueness of urban school systems; determining the influence of these factors upon science teaching research; and articulating a political agenda. Presenters: John Settlage and Paul Jablon

Workshop 7 – Preparing Tomorrow's Science Teachers to Use Technology: A Hands-On Workshop for Beginners **Executive Board Room**
This workshop features hands-on opportunities to learn some of the best technology tools for science instruction, including spreadsheets, the Internet, and Intel's new QX3 computer microscope. Highlighting new "Technology Guidelines for Science Education," emphasis will be placed on using technology to facilitate learning science, rather than on using technology for its own sake.
Presenters: Randy L. Bell and Larry Flick.

Optional Evening Events at AETS 2001

Friday Evening Event 1 – The J. Paul Getty Museum in Los Angeles
Enjoy a night at the famous J. P. Getty Museum in Los Angeles. The museum offers collections of European paintings, drawings, sculpture, illuminated manuscripts, decorative arts, and European and American photographs. (Bus leaves The Westin at 5:10 p.m. Visit the Getty from 6:30 – 9:00, eating dinner at the museum's cafeteria.)
Fee: $15 includes transportation and entrance, not dinner.

Friday or Saturday Evening Event 2 – Kristen Chenoweth at the Orange County Performing Arts Center
Kristen Chenoweth will be performing in a Cabaret Series at Segerstrom Hall of the Orange County Performing Arts Center adjacent to the hotel. A Tony winner for her performance as Sally in You're a Good Man, Charlie Brown, Chenoweth is bound to wow you with her performance. 7:30 p.m. show is $49.00; 9:30 p.m. show is $45.00

Saturday Evening Event 3 – WISE Dessert and Networking
Everyone is welcome to join the Women in Science Education interest group for dessert and networking, Saturday evening from 7:30-9:30 p.m. in the hotel.
Fee: $15.00 includes fruit, pastries, coffee, and tea.

Thursday Afternoon
Concurrent Sessions
1:00-2:00 p.m.

1:00-2:00 p.m.	**T 1.1**	**San Marcos**

Science as Inquiry: Using Replacement Units as Models
Despite decades of teacher education in inquiry-based instruction, many science teachers do not use inquiry as their preferred approach to teaching and learning, even when presented with curricula that are based on inquiry. Join in a dialogue about the implication of this finding for science teacher education.

Presenters: *Roger Bybee,* Biological Sciences Curriculum Study; *Bruce Fuchs,* National Institute of Health

1:00-2:00 p.m.	**T 1.2**	**San Juan**

Preparing Teachers to Address Anti-Science Censors: The Cases of Evolution and Behavioral Genetics

Censoring Science---Alice in Wonderland and Other Fairytales set in Kansas
Censors are using the democratic election process and the populist nature of voters to achieve ends that the monkey trial of the 1920's, the equal time policies of the 1960's, and the Reagan politics of the 1970's could not achieve. This paper will outline the educational-political components of the censorship process and the contrasting ideas between literal biblical interpretations and contemporary evolutionist interpretations.

Presenter: *John R. Staver,* Kansas State University

Will Behavioral Genetics/Sexual Orientation be the Next Target for the Censors of School Science?
As Science learns more of the biological basis of human behavior, science literacy will need to expand to include the big ideas about how genes contribute to behavior, including our sexual orientation. The same persons who want to deny the existence of evidence supporting evolution will likely try to suppress scientific knowledge related to human behavior. This paper focuses on sexual orientation as an important example of behavioral genetics, related threats of censorship, and how teacher education can guard against such threats.

Presenter: *Ron Good,* Louisiana State University

Understanding the Nature of Science: The Potential Contributions to Censorship by Different Views of Science—Inductionists, Absolutists, Falsificationists, and Relativists
Caution needs to be given that the antiscience attracts are not always from outside the scientific community and from the "right". Science teacher educators need to be alert to "this is the truth" dogmatic stance of the traditionalist absolutist view of science and to dilution of canonical science by the "all opinions are equally valid" radical stance of the relativist postmodern view of science. Inaccurate views of science are no less dangerous than book burning, court cases and thought police, and they will put the most vulnerable teachers at risk. This paper will outline the critical epistemological features of a modernist view of science, contrast this view to the epistemology of religion and provide insights for science teacher education.

Presenter: *Norman G. Lederman,* Oregon State University

Preparing Science Teachers for Antiscience Actions: Avoiding Red Flags, Using Proactive Strategies and being Prepared

Science teachers have sound science backgrounds, but they may lack insights into why fundamental religions are threatened by evolution and the age of the earth. Some science teachers introduce controversial "red flag" science concepts without fully developing the ideas or without specific need for doing so. Furthermore, inexperienced science teachers are unaware of the signs of antiscience in their communities. This paper will outline some essential ideas that can be included in pre-service courses and professional development activities for secondary science teachers.

Presenter: *Lawrence C. Scharmann*, Kansas State University

An Elementary Preservice Teacher's Search for Solutions about the Evolution-Divine Creation Question: The Story of Tracy

What are the issues, who are the combatants and how do I address the controversy when I start teaching elementary science? These were the central questions that guided Tracy's quest for solutions. Antiscience controversies are not reserved for the Deep South, the end of the yellow brick road and the USA; the liberal north and Canada also face these controversies. This paper will report on Tracy's search for problem identity, search for solutions and resulting solutions. Her discoveries provide guidelines for ideas and activities that could be included in pre-service courses and professional development activities for generalist elementary teachers.

Presenter: *Larry D. Yore*, University of Victoria

1:00-2:00 p.m.	**T 1.3**	**San Felipe**

Grant Proposal Writing: New Basics for Graduate Science Education

Join us for a review and discussion of a grant proposal writing curriculum that can vary from a short introduction (3 hours) to a full course.

Presenters: *Diana M. Hunn*, University of Dayton: *Lloyd Barrow*, University of Missouri

Exploring Science Teacher Professionalism; Standards and Organizations in the Lives of Science Teachers

Teachers' professional conduct regarding accurately reflecting the nature and content of science correlates with their degree of involvement with National Standards, and professional organization membership. (Weld & McNew, 1999) This study explored those two aspects of teachers' professional lives through a national sampling, using qualitative and quantitative techniques.

Presenters: *Jeffrey Weld*, University of Northern Iowa; *Jill C. McNew*, Oklahoma State University; *Ryan Blake*, Oklahoma State University

1:00-2:00 p.m.	**T 1.4**	**San Carlos**

Equipping Science Teachers with Systematic Tools for Evaluating Instructional Materials: Dynamite in the Hands of Professionals of Amateurs?

This session describes the application, problems, and outcomes of using Project 2001,s instructional materials evaluation framework as a tool in three graduate science methods classes.

Presenter: *Eric J. Pyle*, West Virginia University

Exploration of the Assessment Practices of Elementary Teachers Using Science Kits

This study explored the assessment literacy levels of elementary teachers who had various levels of experience with Science, Technology, and Children kits. Kit users had higher assessment literacy levels in 'developing assessments appropriate for instruction' and for 'recognizing unethical assessment methods'.

Presenter: *Michelle Scribner-MacLean*, University of Massachusetts - Lowell

1:00-2:00 p.m.	T 1.5	San Gabriel

Learning to Look Below the Surface: Employing Videotape Replay to Promote Reflective Practice
This paper describes a videotape replay cycle that we use to assist prospective teachers in framing problems of practice, and to promote systematic inquiry into their teaching.

Presenters: *Lynn A. Bryan and Jeanna Weldon,* University of Georgia

STARS: Evaluating the Use of Video Technology for Modeling Science Process Skills
The STARS project developed a series of videotapes featuring elementary students as role models for inquiry-based science teaching. This session presents an evaluation of the project's impact.

Presenters: *Ken King and Thomas Thompson,* Northern Illinois University

1:00-2:00 p.m.	T 1.6	San Pedro

Assessment and the Development of Learning Communities
This research looks at the development of a learning community over a semester as students use a process of peer and self-assessment with a goal of continuous improvement.

Presenter: *Nancy T. Davis,* Florida State University

Preparing Undergraduate Students as Inquiry Teachers in a Science Methods Course
The study examines undergraduate students' attitudes toward school science and inquiry-based instruction at the completion of a science methods course.

Presenters: *Issaou Gado* and *Norman Fischer,* Kent State University

1:00-2:00 p.m.	T 1.7	San Diego

Assessment Tools and Their Impact on Student Motivation
This investigation explored the impact of different assessment tools on student achievement and motivation. The design of diagnostic, formative, and summative assessment instruments appears to influence student performance and intrinsic motivation.

Presenters: *Melissa King, William Van Evera, Celeste Pea* and *Donna Sterling,* George Mason University

Innovative Teaching and Student Course Evaluations: What Happens When Innovation Meets Evaluation?
This interactive paper discussion will focus on the dilemma of innovative teaching methods and faculty course evaluations. Three different institutional perspectives will be explored.

Presenters: *Starlin D. Weaver*, Salisbury State University; *Beth Shiner Klein,* State University of New York – Cortland; *Juanita Jo Matkins,* University of Virginia

1:00-2:00 p.m.	T 1.8	Capistrano Ballroom

Toward a Personal Philosophy of Science Teaching
Developing a Philosophy of Science Teaching is central in science teacher preparation. Rationale, strategies, and students' philosophies will be examined in scholarly perspective.

Presenters: *Vincent N. Lunetta and Barbara Crawford,* Penn State University

1:00-2:00 p.m.	T 1.9	Laguna Ballroom

Helping Our Pre-service Elementary Students Become Great Teachers
This will be a one-hour interactive working session focused on developing our pedagogical content knowledge (teaching skills and methods) for elementary science methods classes.

Presenters: *Gary Varrella*, George Mason University; *Caroline Beller,* University of Arkansas; *Patty Nason,* Stephen F. Austin University; *Cathy Yeotis,* Wichita State University; *Barbara S. Spector*, University of South Florida; *Joneen Hueni,* Bellville Independent School District

1:00-2:00 p.m.	T 1.10	Viejo Ballroom

A Welcome and Orientation for AETS New Members and First Time Conference Attendees
All first time AETS conference attendees and new members are invited to this welcoming orientation session. Come and learn more about the AETS organization, the annual conference, and meet new colleagues.

Presenters: *J. Randy McGinnis,* University of Maryland; *Pradeep Maxwell Dass,* Appalachian State University; *Penny Gilmer,* Florida State University; *John Schmukler* Temple University, *Greg Stefanich,* University of Northern Iowa; *Judith K. Sweeney,* Natural History and Planetarium, *Peter Veronesi,* SUNY Brockport

Thursday Afternoon Concurrent Sessions 2:20-3:20 p.m.

2:20 - 3:20 p.m.	**T 2.1**	**San Marcos**

Site-Based Professional Development: Learning Cycle and Technology Integration
Participants will discuss unique features of successful projects and other key elements for effective professional development.

Presenters: *Brian L. Gerber*, *Catherine B. Price* and *Andrew J. Brovey,* Valdosta State University

Learning to Teach Science in the High School Context
This demonstration session will present information on how one university science education department is transforming their secondary program by situating the methods block in a high school setting.

Presenters: *Carolyn W. Keys, J. Steve Oliver and Grace Lyon,* University of Georgia

2:20 - 3:20 p.m.	**T 2.2**	**San Juan**

Preliminary Evaluation of a Professional Development Program for High School Science Teachers
This presentation describes the evaluation of the first component of a three-year teacher development project emphasizing molecular biology.

Presenters: *Eric A. Hagedorn*, *Dianne Bowcock* and *Michael Patrick*, University of Wisconsin; *Tim Herman,* Milwaukee School of Engineering

Professional Development as Inquiry: The Role of Formative Assessment in Professional Development
Three national professional development efforts engaged in inquiry-based science education reform describe their teacher-based research on the effect of formative assessment on professional development.

Presenters: *Doris Ash,* San Francisco Exploratorium; *Lin Tucker,* Cambridge Public Schools; *Karen Levitt*, Duquesne University

2:20 - 3:20 p.m.	**T 2.3**	**San Felipe**

The Learning to Teach Science with Technology Project
The Learning to Teach Science with Technology project at Penn State will be described. The project helped prospective elementary and secondary science teachers learn inquiry science through technology, increase proficiency in the use of science-specific technology, and then teach technology-enhanced lessons. Unique and effective project features will be highlighted.

Presenters: *Kathleen Sillman*, *Carla Zembal-Saul*, *Patricia Friedrichsen*, *Barbara Crawford*, *Tom Dana and Vincent N. Lunetta*, Penn State University

2:20 - 3:20 p.m.	T 2.4	San Carlos

A Comparative Analysis of Science Teacher Education in Fifteen Countries
This panel discussion will provide a comparative analysis of issues and perspectives that arise during the professional development of science teachers in fifteen countries.

Presenters: *Pamela Fraser-Abder*, New York University; *Deborah Tippins*, University of Georgia; *Sherry Nichols*, East Carolina University; *Norman Thomson*, University of Georgia; *June George*, University of West Indies

2:20 - 3:20 p.m.	T 2.5	San Gabriel

Infusing Technology to Enhance Science Lessons: Prospective Teachers as Action Researchers Learning to Teach for Conceptual Change
Presenter will describe a reflective approach to technology training for preservice teachers who are learning to teach chemistry, blending elements from collaborative action research and teaching for conceptual change.

Presenter: *Randall Spaid*, Florida State University

Promoting Preservice Students' Understanding of the Nature of Science through Collaborative Learning
This study investigated the impact of a college chemistry lab course designed to provide pre-service students with inquiry-based, collaborative learning experiences across two universities, in order to promote greater understanding of the nature of science.

Presenters: *John W. Tillotson* and *Moses Ochanji*, Syracuse University

2:20 - 3:20 p.m.	T 2.6	San Pedro

R-Best Rationale: What Do We Know After Four Years?
This paper continues the discussion surrounding the impact of a research-based elementary science teaching rationale with pre-service teachers and follows with additional data from in-service teachers.

Presenters: *Peter Veronesi*, SUNY Brockport; *Gary Varella*, George Mason University

Professional Development for Elementary School Teachers Working With Science Learning Outcome
This pilot case study examined elementary school teachers' professional development needs with a teacher focus group collaboratively planning from a new and different science curriculum.

Presenters: *Ken Appleton and Allan Harrison*, Central Queensland University

2:20 - 3:20 p.m.	T 2.7	San Diego

When Do Science Teachers Learn to Teach? A Comparison of Children's and Preservice Teachers' Science Teaching Illustrations
Science teaching illustrations of elementary and secondary students, compared with those of elementary pre-service science teachers, present similarly stereotypical science teaching perceptions.

Presenters: *Julie Thomas*, Texas Tech University; *Jon E. Pederson*, University of Oklahoma

Views of Nature of Science Questionnaire (VNOS): Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science
This paper presents a new instrument, the VNOS, which in conjunction with interviews, is intended to provide valid and meaningful assessments of learners' views of nature of science.

Presenters: *Fouad Abd-El-Khalick,* University of Illinois at Urbana-Champaign; *Norman G. Lederman,* Oregon State University; *Randy L. Bell,* University of Virginia; *Renee Schwartz,* Oregon State University

2:20 - 3:20 p.m.	**T 2.8**	**Capistrano Ballroom**

Research-Based Framework: Directions for Researchers
Science educators experienced in preparing pre-service students to write and orally defend a research-based framework for teaching science will propose directions for future research regarding this approach.

Presenters: *Michael P. Clough, Joanne K. Olsen* and *Brian Hand,* Iowa State University; *Paul Numedahl,* Colorado College; *John E. Penick* North Carolina State University; *Craig A. Berg,* University of Wisconsin – Milwaukee

2:20 - 3:20 p.m.	**T 2.9**	**Laguna Ballroom**

Challenging Our Thinking on the Nature of Reform in Science Teacher Education
This interactive session focuses on how we can "make a difference" in science teacher education experiences within the context of reform in science education. We will focus on developing a template for a working agenda and action plan about essential teacher education experiences for pre-service and in-service science teachers, where we bridge the gap between "academic" and "popular" theorizing.

Presenter: *Patricia Simmons*, University of Missouri-St. Louis

Evolution from Graduate Student to Professor with Tenure
This session will discuss potential higher education positions and typical responsibilities, including job interview strategies and professional activities that facilitate achieving tenure.

Presenter: *Lloyd H. Barrow*, University of Missouri

2:20 - 3:20 p.m.	**T 2.10**	**Viejo Ballroom**

AETS: The Who, When, Why, and How
This interactive session will help members of AETS become more familiar with how the organization operates. Through discussions of the by-laws and standard operating procedures, participants will get a better understanding of how to become active on committees and on the board.

Presenters: *Molly Weinburgh,* Georgia State University; *Julie Gess-Newsome,* Northern Arizona University; *John Staver,* Kansas State University

3:20 - 4:00 p.m.	**Coffee Break**	**East Galleria**

4:00 – 5:15 p.m. **AETS KEYNOTE ADDRESS**
Costa Mesa and Santa Ana Ballrooms

INCLUSIVE EDUCATION: THE POSSIBLE FUTURE(S) OF EDUCATION

Keynote Speakers: Dr. *Richard Villa,* Bayridge Consortium, Inc.
Dr. Jacqueline Thousand, California State University, San Marcos

Dr. Villa and Dr. Thousand have authored numerous books, research articles and book chapters on practical how-to strategies for meeting the needs of all students in general education; adapting curriculum, instruction, and assessment; collaborative teaming; co-teaching; and creative problem-solving. Both have extensive experience working with educational opportunities for students with various disabilities and/or who are at-risk for school failure. Their keynote will address characteristics of successful inclusionary schools; implementation of recent legislative mandates; and implications for science teacher preparation.

5:15 – 7:15 p.m. **Reception and Poster Session** **East Galleria**
T 2.11

Academic Controversy as a Science Teaching Strategy
The purpose of this study was to determine the effects of academic controversy as a teaching strategy in elementary science methods classes.

Presenters: *Rebecca M. Monhardt and Leigh C. Monhardt,* Utah State University

Factors Influencing the Amount of Science Taught in the Elementary School Curriculum: The Teachers' Perspective
This qualitative study seeks to develop a greater understanding of the factors that are shaping the elementary school curriculum, from the perspective of the teachers.

Presenter: *Cassie R. Carter,* University of Southern California

What We Know About Students' Cognitive Conflict in the Science Classroom: A Theoretical Model of Cognitive Conflict Process
The purpose of this study is to explain cognitive conflicts of students who were confronted with anomalous situations in learning science. We reviewed a lot of related literature and interviewed four students in a science class.

Presenters: *Gyoungho Lee,* Ohio State University; *Jaesool Kwon,* Korea National University of Education

Touching Viruses Across Space: Nanotechnology Outreach and Science Inquiry
In two pilot programs, students manipulated and touched viruses with new technology through the WWW. As part of a week long unit, students used a nanoManipulator and Atomic Force Microscope, interviewed scientists, and examined models of viruses. Students gained an understanding of viral structure and understanding of scientists and the nature of scientific research.

Presenters: *Gail Jones, Richard Superfine and Russell M. Taylor II,* University of North Carolina-Chapel Hill; *Thomas Andre*, Iowa State University;

Thinking Reflectively Rather than Reflexively: Portfolio Development in Teacher Education
Reflection fostered by portfolio development enhances teacher metacognition, particularly by thinking about why to use teaching strategies rather than simply knowing how to use them.

Presenter: *Christopher Anderson,* Ohio State University

Mini-grant Writing for Middle and High School Science Teachers
Description of a brief assignment in writing short, small, readily fundable grants for science teachers, together with a writing guide and a list of funders.

Presenter: *Dan MacIsaac,* Northern Arizona University

Pre-service Science Teachers as Cultural Agents: A Transformative Study
This study attempted to assist secondary science pre-service students in constructing alternatives to traditional science instruction in order to enhance their effectiveness when working with diverse students.

Presenters: *Carolyn A. Butcher and Gilbert Valadez,* Radford University

Supporting Teachers in an Integrated Science Curriculum
Voyages Through Time is an integrated science curriculum, based on the theme of evolution. Multiple teacher supports are being included for implementing the curriculum.

Presenter: *Kathleen A. O'Sullivan,* San Francisco State University

The Fresno Collaborative for Excellence in the Preparation of Teachers
This session will share the many exciting components of the NSF-funded Collaborative for Excellence in Teacher Preparation Project based in Fresno, California.

Presenters: *David M. Andrews,* California State University, Fresno; *Jaime Arvizu,* Fresno Collaborative for Excellence in the Preparation of Teachers

S'Cool Students Look To the Skies in a Worldwide Collaborative Effort to Assist NASA's Ceres Project
Students from 37 countries have their eyes focused on the clouds as they monitor weather conditions and report to NASA. Collected data validates important research.

Presenters: *Doug Stoddard and Lin H. Chambers,* NASA

Inquiry-Based Research Articles Published by Elementary Students in the I Wonder Journal (1992-2000)
Analyses of elementary student research articles published in I Wonder: The Journal for Elementary School Scientists examined students' research questions and investigative procedures from 1992-2000.

Presenters: *Michael E. Beeth, Tracy Huziak and Christopher Anderson,* Ohio State University

Educational Ecology: Using the Conceptual Framework of Ecology to Teach Secondary Science Methods
This paper describes the design and implementation of a course that uses the conceptual framework of ecology as a model for teaching secondary science methods.

Presenter: *Fletcher Brown,* University of Montana

Empowering Girls to Achieve in Science
We can counteract the trends in declining science achievement for girls in middle school and high school. Girl Power representative will share how we achieve results.

Presenters: *Nancy Stubbs and Caryn Hoffman*, Sweetwater Union High School District

The Effect of Teaching Outdoor, Environmental Education on Pre-service Teachers' Attitudes Toward Self-Efficiency and Outcome Expectancy
The study examined the effect of training and participation in an outdoor environmental education project on pre-service teachers' ability to teach environmental education with positive self-efficacy.

Presenters: *Chris Moseley and Kay Reinke,* Oklahoma State University

Investigating a Professional Development Project for University Scientists: Successes and Struggles in Implementing Inclusive Instructional Strategies
Using an ethnographic frame, the views and self-reported practices of scientists involved in a professional development seminar on issues of inclusion were explored.

Presenter: *Julie Bianchini*, University of California, Santa Barbara

Harmonizing the General Chemistry Laboratory with Lecture at a Large University
Provides an overview of insights learned from Operation CHEM 1251. The project involves restructuring the first-semester general chemistry program at UNC Charlotte.

Presenters: *Warren J. DiBiase*, University of North Carolina, Charlotte; *Eugene P. Wagner II*, University of Pittsburgh

Action Research Pertaining to Special Education Populations in Science Classrooms
Middle school science lessons were observed for classroom interactions, attitudes and achievement as it related to the topic of mainstreaming special education students within regular classrooms. Classroom observations, surveys and achievement scores were compiled on three separate populations of students.

Presenters: *Nedra J. Davis, Sulaiman al-Balushi, Robert Masene, Lisa Martin, Mee Kyeong Lee, Chia-Jung Chung, Heeyoung Cha, Carolyn White and Boyd Harris*, University of Iowa

Harmonizing the General Chemistry Laboratory with Lecture at a Large University
Presenters: *Eugene P. Wagner II*, University of Pittsburgh; *Warren J. DiBiase*, University of North Carolina

Standards-Based Assessment Practices: Consistencies, Inconsistencies and Implications for Practice
The assessment practices of a high school teacher are examined through the lens of the National Science Education Standards. Implications for professional development are presented.

Presenter: *Edith S. Gummer*, Oregon State University

Elementary Prospective Teachers' Use of an Online Communicative Tool: Implications for the Use of Technology in Science Teaching Preparation
This study examined the nature of prospective elementary teachers' electronic discourse as they reflected on events and their experiences with teaching technology-enriched science lessons.

Presenters: *Lucy Avraamidou and Barbara A. Crawford*, Penn State University

Investigating Critical Junctures in Project-Based Learning in Science Methods Classes
This study focuses on the scaffolding between instructors and groups of students as they develop science investigations in project-based university methods classes.

Presenters: *Scott Lewis and George E. O'Brien*, Florida International University; *Charlene M. Czerniak* University of Toledo; *Lena Ballone*, Bowling Green State University

An Informal Introduction to Strategies for Developing Pre and In-Service Elementary Science Teachers
Elementary Science Teacher Leadership (ESTL) is a teacher-enhancement project supported by the Exxon-Mobil Education Foundation. The project is providing pre and in service teacher educators with resources they can use to enhance the understanding of science and approaches to teaching for their students.

Presenters: *Herbert D. Thier and Marlene Thier*, Lawrence Hall of Science – University of California, Berkeley

Friday Morning

6:30 - 8:00 a.m.	Continental Breakfast With AMTE	East Galleria

Concurrent Sessions
8:00 – 9:00 a.m.

8:00 - 9:00 a.m.	F 1.1	San Marcos

A Council of Beings: Using Focused Free-Writing and Anthropomorphism to Ascertain Worldview and Science Content Knowledge in Environmental Education
A focused free-writing activity designed to ascertain students' understanding of their relationship to the earth from a scientific, natural history, philosophical and affective domain perspective.

Presenter: *Margaret B. Bogan,* Florida Gulf Coast University

8:00 - 9:00 a.m.	F 1.2	San Juan

Teacher Designed Tech-Based Science Centers: A Demonstration
This session will demonstrate multi-media, asynchronous, inquiry-oriented science center activities developed by K-8 teachers as a strategy to meet state and national science standards. All of the projects make use of technology typically found in schools.

Presenters: *Tony Lorsbach and Jerry Jinks,* Illinois State University

Helping Pre-Service Teachers Integrate Technology in the Elementary Classroom
This presentation will focus on an action research program involving science methods classes. Cooperating teachers, university faculty and pre-service teachers work together to develop technology integration plans.

Presenters: *Julia McArthur and Lena Ballone,* Bowling Green State University

8:00 - 9:00 a.m.	F 1.3	San Felipe

Pre-service Teachers' Perceptions of Themselves as Researchers
To evaluate a residential science research experience, pre-service teachers were given a pre-post instrument to measure changes in their view of themselves as science researchers.

Presenters: *Debra A. Hemler,* West Virginia University; *Aimee L Govett,* University of Nevada, Las Vegas

Not All "A's" are Created Equal: An Inquiry Science Endorsement for Pre-service Teachers
The Inquiry Science Endorsement is a collaborative effort designed to establish consistent competencies in teaching science for new teachers from three universities. Districts use ISE for hiring new teachers.

Presenter: *Karen Levitt,* Duquesne University

8:00 - 9:00 a.m.	F 1.4	San Carlos

Science and Language Links
This action research project studied the reciprocal relationship of science and language literacy development in the context of inquiry lessons in a fourth grade classroom.

Presenters: *Zale Liu and Valarie Akerson,* Washington State University

Learning Science Through Reading: Fifth-grade Students Conceptualization of "Observation."
This study explores fifth-grade students' understanding of "observations" via children's literature texts that model different degrees of observation and facilitate discourse concerning the nature of observation.

Presenter: *Francis S. Broadway*, The University of Akron

8:00 - 9:00 a.m.	**F 1.5**	**San Gabriel**

First-Year Science Teachers as Partners: Learning to Teach Together in a Job-Sharing Arrangement
Two fifth-year program pre-service teachers job-shared a middle school science teaching position in lieu of student teaching. Their first year story teaching as partners will be shared.

Presenters: *Charles J. Eick and William E. Baird*, Auburn University

Making Co-Teaching Work - a Field Experience in a Science Methods Course: What We Have Learned During the First Year
An overview of the first year in a science methods course utilizing co-teaching within the field experience.

Presenter: *Charles J. Eick*, Auburn University

8:00 - 9:00 a.m.	**F 1.6**	**San Pedro**

From Science Professor to Science Teacher
This session will focus on the professional development activities of a college professor as he learned to use inquiry and other active learning formats in his college classroom. This professor eventually began to teach in an 8th grade science classroom using these same teaching techniques.

Presenters: *Meta Van Sickle and William Kubinec*, College and University of Charleston

Preparing College Science Teachers
This presentation will address science teacher preparation for college-level teaching. An exemplary program will be described, and problems and perspectives will be discussed.

Presenter: *Marvin Druger*, Syracuse University

8:00 - 9:00 a.m.	**F 1.7**	**San Diego**

CASIO QV 2800UX Digital Camera
Educators will be fascinated to see what a difference digital camera technology can make in their classrooms. Digital cameras are one of the single most successful learning technology purchases a school can make. The CASIO digital camera is a superb learning tool with the ability to view images instantly on the LCD screen of the camera, a TV, or a computer. Educators will leave with an understanding of the 21st century possibilities using one of the best educational technologies.

Presenter: *Leilani Morales*, CASIO Educational Support Specialist

8:00 - 9:00 a.m.	**F 1.8**	**Capistrano Ballroom**

Conversation on Science Education by Montessori, Piaget, and Vygotsky
In a conversation format, this panel symposium presentation will address Montessori's, Piaget's, and Vygotsky's constructivist epistemologies and their implications for science teaching and learning.

Presenters: *Gado Issaou, Doris Simonis and Geeta Verma*, Kent State University

8:00 - 9:00 a.m.	F 1.9	Laguna Ballroom

A Quality Alternative Field Experience for Developing Preservice Students' Teaching Skills
This paper explores a strategy developed to place pre-service students in a more authentic and non-traditional experience – that of teaching a summer camp for middle school children.

Presenter: *Gary F. Varrella,* George Mason University

Defining Features of STS: Implementation and Interpretations at Two University Sites
The discussion will focus on the utility of STS as one pivot-point of science methods courses. Experiences and strategies that support STS-oriented instruction in science methods (or content courses) will be the focus of this discussion.

Presenters: *Gary F. Varella,* George Mason University; *Rebecca Monhardt and Leigh Monhardt,* Utah State University

8:00 - 9:00 a.m.	F 1.10	Viejo Ballroom

Does Being Wrong Make Kettlewell Wrong for Science Teaching?
Discrepancies between the "classic" textbook account and what is actually known about the phenomenon of industrial melanism, augmenting its value for science teaching, will be presented.

Presenter: *David W. Rudge,* Western Michigan University

Contextualized Nature of Science Instruction: A Success Story
Six teachers in a course emphasizing both decontextualized and contextualized nature of science teaching strategies were observed throughout the fall 1999 semester. Implementation of the nature of science exceeded that reported in most prior studies.

Presenters: *Joanne K. Olson and Michael P. Clough,* Iowa State University

Friday Morning Concurrent Sessions 9:20-10:20 a.m.

9:20 - 10:20 a.m.	F 2.1	San Marcos

Deepening Conceptual Understanding in Middle School Life Science: Energy in the Human Body
This interactive session will present a curriculum designed to produce deeper conceptual understanding that involves development of complex visual models.

Presenters: *Mary Anne Rea-Ramirez,* Hampshire College; *Helen Gibson,* Holyoke School District; *Maria C. Nunez,* University of Massachusetts

9:20 - 10:20 a.m. | **F 2.2** | **San Juan**

Learn by Doing: Pre-Service and In-Service Science Teachers Experience New Computer Technology for Use in Their Science Classrooms
This presentation focuses on the opportunities available in the modern science classroom and the experiences needed to prepare science teachers for those classrooms. The discussion will include the computer technology uses learned by pre-service and in-service science teachers.

Presenters: *Elaine J. Anderson and Jody Fry,* Shippensburg University

9:20 - 10:20 a.m. | **F 2.3** | **San Felipe**

Raytheon Teaching Fellows Program
Description of a corporate-funded program to recruit and mentor science and mathematics teachers. Presenters will share results from the first year of the program.

Presenters: *Catherine G. Yeotis, David R. Alexander, Judith L. Hayes and Mara Alagic,* Wichita State University

Attitudes of Science Teachers and Principals during Implementation of a State Systemic Initiative– Implications for Science Teacher Education
From 1995 to 1998, data were collected annually from principals and science teachers as part of Ohio's SSI. This presentation provides a summary of how principals and science teachers rated and ranked 10 critical issues over the period of the study.

Presenters: *William J. Boone,* Indiana University; *Jane Butler Kahle,* Miami University

9:20 - 10:20 a.m. | **F 2.4** | **San Carlos**

Multi-Institutional Initiative to Improve Undergraduate Science and Mathematics Education
The results of three major conferences on undergraduate science and mathematics education will be reviewed and compared with an emphasis on the implications for reform for undergraduate curriculum and instruction.

Presenters: *J. Preston Prather,* University of Tennessee at Martin; *Jack Rhoton,* Eastern Tennessee State University; *Khristin Rearden,* University of Tennessee

9:20 - 10:20 a.m. | **F 2.5** | **San Gabriel**

Building University and School District Partnerships
Find out how your university can participate in a five-year NSF-funded professional development project. In this session, we will describe an opportunity for developing partnerships between the SCI Center at BSCS, universities, and school districts. This project includes work with systemic initiatives to support joint efforts in science reform.

Presenters: *Janet Carlson Powell and Jim Short,* Biological Sciences Curriculum Study

9:20 - 10:20 a.m. | **F 2.6** | **San Pedro**

Science Education and Cultural Agency
In this session, the presenters will initiate a discussion on how teachers can impact cultural change through the examination of cultural patterns in science instruction.

Presenters: *Gilbert Valadez and Carolyn A. Butcher,* Radford University

The Role of Science Educators in Helping Prevent Language and Cultural Extinction
This paper presents an overview of Kenyan education since European colonization and independence. Currently, Kenya's educational system is being restructured. This session should particularly benefit conference attendees who are interested in issues surrounding cultural extinction.

Presenter: *Norman Thomson,* University of Georgia

9:20 - 10:20 a.m.	**F 2.7**	**San Diego**

NASA Presentation
Educators and administrators for grades 3-8 will receive information about two FREE standards-based, technology-focused, integrated mathematics, science and technology distance learning programs. The NASA "WHY?" Files and NASA CONNECT – produced by NASA Langley Research Center's Office of Education. Participants will learn how to incorporate technology into their lessons using NASA programs and NASA research.

Presenters: *Thomas Pinelli,* NASA Office of Education; *Peg Steffen,* NASA Headquarters

9:20 - 10:20 a.m.	**F 2.8**	**Capistrano Ballroom**

Analyses of the First Reader's Survey of the Electronic Journal of Science Education
Results of the readers' surveys of the Electronic Journal of Science Education are presented. Technological expertise, value of publication, and subscription rates are examined.

Presenters: *John R. Cannon and David T. Crowther,* University of Nevada, Reno

Integrating Technology into Teacher Preparation for K-12 Classrooms
Integrating Technology into Teacher Preparation (ITTP) develops and implements an innovative environment for interfacing technology with mathematics and science education in teacher education and K-12 learning.

Presenters: *Vickie Harry and Elaine Carbone,* Clarion University

9:20 - 10:20 a.m.	**F 2.9**	**Laguna Ballroom**

Technology: Pre-Service Teachers' Preparation: Oil: Water?
Methods instructors throughout the State of Oregon were surveyed to determine how pre-service teachers are prepared to use technology in their math and science teaching.

Presenters: *Patricia D. Morrell and James Carroll,* University of Portland

Every Student with a Laptop: Initial Impacts on Science Teacher Preparation
This session includes a demonstration of classroom uses of technology and a discussion of issues surrounding an initiative in which all students have laptop computers.

Presenters: *Carolyn Dawson and Rita Hrecz,* Northern Michigan University

9:20 - 10:20 a.m.	**F 2.10**	**Viejo Ballroom**

Tearing Up the Book: A Whole Class Reading Strategy for Science and Mathematics Classrooms
Tearing up the book is a reading, listening, speaking activity that stimulates students' intrinsic competencies to think and communicate orally. Participants in this session will gain an understanding of the teacher preparation requirements, and read a book as a group demonstration. A list of potential reading materials for the high school science and mathematics curriculum will be available.

Presenter: *Jan Wilson,* Jacksonville State University

A Study of the Impact of Writing-Intensive Instruction on Students' Understanding of Mathematics and Science
Student performance on written assessments will provide indicators of the impact of a writing-intensive unit in mathematics and science.

Presenters: *David K. Pugalee,* University of North Carolina-Charlotte

9:20 - 10:20 a.m.	**F 2.11**	**Executive Board Room**

Using Electronic Classrooms and the World Wide Web to Support Science Teaching and Learning
This interactive panel symposium will highlight the ways in which many instructors are creating on-line classrooms to support existing coursework. Presenters will model how Nicenet, WebCT, etc. can be used to support pre-service and in-service teachers.

Presenter: *Paul Vellom and Michael Beeth,* Ohio State University; *Marcia Fetters,* University of Toledo

Friday Morning Concurrent Sessions 10:40-11:40 a.m.

10:40 - 11:40 a.m.	**F 3.1**	**San Marcos**

Designing A Physics Laboratory Course to Meet the Needs of Pre-Service Teachers
Opinions of five students who participated in a pilot, lab-guided development course. Nature of science and sequence of lab and lecture were important considerations.

Presenter: *Constance Haack,* University of Kansas

Presentation and Discussion of an Online Distance Education Course on Earth and Environmental Sciences for Pre-Service and In-Service Teachers
This interactive, demonstration session will address how online, distance education courses provide for a variety of educators to enhance their knowledge regarding national science standards and associated reform efforts currently being undertaken throughout the country. Information rich opportunities for professional development are made readily accessible to learn and apply science education reform concepts and standards.

Presenter: *Dennis Kubasko,* University of North Carolina-Chapel Hill

10:40 - 11:40 a.m.	**F 3.2**	**San Juan**

What Knowledge is of Most Worth for Lateral Entry Secondary Science Teachers?
A committee of university science educators and expert secondary science teachers developed a curriculum reflecting what knowledge is of most worth for a lateral entry program.

Presenter: *William R. Veal,* University of North Carolina-Chapel Hill

Barriers and Pathways: An Examination of an Induction Program for Secondary Science Teachers
There is a need for universities and school districts to collaboratively develop support programs for beginning science teachers. In this presentation we will discuss one such program and the barriers and pathways we have encountered along the way.

Presenters: *Julie A. Luft, Gill Roehrig and Nancy Patterson,* University of Arizona; *Teresa Potter,* Rio Rico High School; *Barry Roth,* Tucson Unified School District

10:40 - 11:40 a.m.	F 3.3	San Felipe

Knowing the Scientific Method, Beliefs, and Student Inquiry
Case studies of three middle school teachers implementing inquiry will be presented. These teachers had contrasting successes, views of science, and pedagogical beliefs. The relation between their classroom practices and beliefs will be explored.

Presenters: *Deborah J. Trumball,* Cornell University; *Grace Scarano,* University of New England

Prospective Science Teachers, Knowledge of Inquiry-Based Instruction in a Secondary Methods Course
This presentation will discuss prospective science teachers' beliefs and understandings of inquiry-based instruction, and how this knowledge is used to plan for inquiry-based lessons in methods course-context and school-context.

Presenters: *Chen Tsur and Barbara A. Crawford,* Penn State University

10:40 - 11:40 a.m.	F 3.4	San Carlos

Being There and Not Being There: The Experience of Teaching an Elementary Science Education Course on the Internet
This study explores the experience of teaching an elementary science education course to in-service teachers pursuing a graduate degree in Mathematics, Science and Technology. What science teacher educators can learn about teaching and learning from meeting a class of graduate students on the web, and what students experienced from interacting in this learning environment will be the topics of this presentation.

Presenter: *Janice Koch,* Hofstra University

Creating WebQuests in an Elementary Science Methods Course
A web-based instructional strategy was integrated into a science methods course for elementary teachers. Reported benefits included use of technology and quality instruction.

Presenter: *Mark D. Guy,* University of North Dakota

10:40 - 11:40 a.m.	F 3.5	San Gabriel

The Theory and Practice of Science, Technology, Society Orientations
This interactive session focuses on the development of rich/extended units of inquiry, learning environments supporting the development of complex reasoning and holistic development in adolescence.

Presenters: *Chris L. Lawrence,* Florida State University; *Robert E. Yager,* University of Iowa; *Ann Guilbert,* University of Texas at Tyler; *Elizabeth Hancock, Felicia Moore, Scott Sowell, Yalcin Yalaki and Chad Slaughter,* Florida State University

10:40 - 11:40 a.m.	F 3.6	San Pedro

Eighth-grade African American Students, Sense-making about Electricity
This study explores the prior knowledge of eighth-grade African American students with respect to electricity and its implications to conceptual change instruction and multicultural education.

Presenters: *Morgan C. Greene and Francis S. Broadway*, The University of Akron

African American High School Students as Teacher Educators for Urban Science Teachers
African American high school students took an active role in science curriculum development and the science methods course in an urban teacher education program.

Presenter: *Gale Seiler*, University of Pennsylvania

10:40 - 11:40 a.m.	F 3.7	San Diego

Inclusive Science Education – Model Lessons
Participants will experience lesson sequences reflecting inclusive practice with suggestions and modifications for students in twelve disability categories. Research on best practice will be shared.

Presenter: *Greg P. Stefanich*, University of Northern Iowa

Making Science Accessible: Strategies for Modifying Science Activities to Meet the Needs of a Diverse Student Population
Come and learn how to take favorite science activities and modify them to meet the needs of students with physical and/or learning disabilities.

Presenters: *Marcia K. Fetters*, University of Toledo; *Dawn Pickard*, Oakland University; *Eric Pyle*, West Virginia University

10:40 - 11:40 a.m.	F 3.8	Capistrano Ballroom

Trends in Earth/Space Science Education and Kentucky's Online Response to Key Issues
This study compares Kentucky's Earth/space Science education to national trends. Areas of need including teacher certification deficiencies are identified and an online course initiative is reported.

Presenter: *Kathy Cabe Trundle*, University of Alabama

Results of an Environmental Education Needs Assessment of K-12 Teachers
This session will focus on the priority environmental education program and training needs of teachers identified through survey and follow-up focus group interview results.

Presenter: *Yvonne Meichtry*, Northern Kentucky University

10:40 - 11:40 a.m.	F 3.9	Laguna Ballroom

Rationale Papers in Methods Courses
A panel discussion on the use of rationale papers by pre-service teachers will be discussed by faculty who use them.

Presenters: *Robin Lee Harris*, Buffalo State College; *John E. Penick*, North Carolina State University; *Ron Bonnstetter*, University of Nebraska; *Pradeep M. Dass*, Northeastern Illinois University; *Sandy Enger*, University of Alabama at Hunstville; *John W. Tillotson*, Syracuse University; *Gary F. Varrella*, George Mason University; *Peter Veronesi*, SUNY Brockport; *Jeffrey Weld*, Oklahoma State University

10:40 - 11:40 a.m.	F 3.10	Viejo Ballroom

An Examination of the Relationship among Science Teaching Actions, Beliefs, and the Knowledge of the Nature of Science
A qualitative study on the relationship between secondary science teachers' own beliefs and pedagogical actions with regard to the nature of science.

Presenters: *Sajin Chun and J. Steve Oliver*, University of Georgia

Schematic Modeling as an Explanation for the Nature of Science
Learning is a process of modeling and model building. This process can enhance the understanding of pre-service and practicing teachers of the nature of science and scientific knowledge, and the reasons for constructivist inquiry.

Presenter: *Steven W. Gilbert,* Indiana University Southeast

11:45 - 1:15 p.m. **F 4.1**

AETS Box Lunch and Committee Meetings

* Please pick up your box lunch in **East Galleria** prior to going to committee meetings.
- Ticket, included in registration packet, is needed in order to pick up your lunch.

Elections Committee	**San Marcos**
Long Range Planning	**San Marcos**
Financial Advisory	**San Juan**
Awards	**San Juan**
Inclusive Science Education	**San Felipe**
Informal Science Education	**San Carlos**
Program	**San Gabriel**
Political Action	**San Pedro**
Liaisons with Professional Organizations	**San Diego**
Regional AETS Units	**Capistrano Ballroom**
Membership and Communication	**Laguna Ballroom**
Publications	**Viejo Ballroom**

Friday Afternoon
Concurrent Sessions
1:20 – 2:20 p.m.

1:20 - 2:20 p.m.	F 5.1	San Marcos

Science Cases with Science Concepts on the Visible Horizon
A case study that addresses science concepts and issues will be facilitated. Case study development will be delineated, and sample case studies will be distributed.

Presenter: *Sandra K. Enger,* University of Alabama at Huntsville

Language Development and Science Inquiry
This presentation will discuss a model that fosters science learning through a systematic approach to language development. Students improved their content knowledge along with their ability to answer questions requiring higher cognitive levels.

Presenters: *Penny L. Hammrich and Evelyn R. Klein,* Temple University

1:20 - 2:20 p.m.	F 5.2	San Juan

Elementary M.A.T. Interns' Perceptions of Science Teaching
The presenter will share illustrations that elementary education M.A.T. interns drew of science teachers. The analysis of the drawings was based on the DASTT-C instrument.

Presenter: *G. Nathan Carnes*, University of South Carolina

Using Classroom Research to Foster Pre-Service Teachers' Abilities to Critically Analyze Their Science Teaching
In a fifth year M.A.T. program, classroom research was utilized to cultivate pre-service teachers' abilities to analyze their conceptions of effective science teaching and learning.

Presenter: *Paul Numedahl,* Colorado College

1:20 - 2:20 p.m.	F 5.3	San Felipe

Four Forgotten Dimensions for Science Methods Courses: Imagination, Visual/Spatial Thinking, Enthusiasm and a Sense of Mission
A review of science methods courses found a lack of concerted emphasis on four key dimension of human potential development. Remedies are recommended.

Presenter: *Alan J. McCormack,* San Diego State University

An Ecological Model of Science Teacher Preparation
A model of science teacher education is developed using observational and other data. This model reveals problems of the standard mechanistic approach of college science.

Presenter: *Don Duggan-Haas,* Kalamazoo College

1:20 - 2:20 p.m. | F 5.4 | San Carlos

Examining Discourse in Elementary Science Methods: Differences between Science Content and Pedagogy
We compare discourse strategies during two foci of instruction, science and pedagogy, in a methods course and include the instructor's reflections on classroom discourse.

Presenters: *William J. Newman, Jr., Paula D. Hubbard and Sandra K. Abell,* Purdue University

Field Experiences that Serve the Elementary Classroom Teacher
Elementary science methods students provide science learning opportunities for local schools extending field experiences into service learning.

Presenter: *Peggy J. Tilgner,* Wartburg College

1:20 - 2:20 p.m. | F 5.5 | San Gabriel

Science Work Experience Programs for Teachers: Refocusing Professional Development Using a Qualitative Lens
Interviews and classroom observations document a program participant's lived experience and the effect of a Science Work Experience Program for Teachers on the classroom environment.

Presenter: *Wendy Frazier,* Columbia University

Georgia Teacher Support Specialist in Science: An On-Line Learning Experience
Come hear about the lessons learned from a three-campus collaboration that involved on-line learning experiences to prepare mentor teachers.

Presenters: *Thomas Koballa, Mai Yin Tsoi and Leslie Upson,* University of Georgia; *Brian Gerber,* Valdosta State University; *Susan Gnnaway,* North Georgia College & State University; *Dava Coleman,* Cedar Shoals High School

1:20 - 2:20 p.m. | F 5.6 | San Pedro

An Extension of Analysis on the Self-Efficacy Beliefs about Equitable Science Teaching
At the AETS 2000 meeting, two members of this research group presented an overview of steps they used for the development of a new measurement scale, entitled the SEBEST, which measures the self-efficacy beliefs of prospective elementary teachers toward equitable science teaching. In this presentation, the issues of scale operation will be presented as well as how this particular instrument, the SEBEST, might best be used with students.

Presenters: *Jennifer Ritter,* Millersville University; *Peter Rubba,* Penn State University; *William Boone,* Indiana University

Modifying Scientific Inquiry for Mainstreamed Students
This is the third in a series of projects focusing on strategies to modify science instruction to address the needs of students with special learning needs.

Presenter: *Kevin D. Finson,* Western Illinois University

1:20 - 2:20 p.m.	F 5.7	San Diego

Experience Plus Reflection Equals Growth: A Performance Assessment System for Pre-Service Teachers
A teacher preparation program structured around a comprehensive performance assessment system is described. Pre-service teachers build portfolios containing evidence that demonstrates fulfillment of Beginning Teachers Standards.

Presenter: *Richard H. Audet,* Roger William University

Teacher Portfolios: Pathways to Teacher Empowerment
Teacher portfolios can be used as a professional development tool to show growth and improvement. Experiences using them in an innovative Master's program will be shared.

Presenter: *Judy Beck,* University of Wisconsin – La Crosse

1:20 - 2:20 p.m.	F 5.8	Capistrano Ballroom

Reforming the Reformers: Conceptual Change of Scientists' Conceptions of Teaching and Learning
The teaching practices of three science faculty were examined through the lens of conceptual change. Within this perspective, the impact of using an NSF grant to stimulate reform-based change in thinking and practice was assessed.

Presenters: *Julie Gess-Newsome,* Northern Arizona University; *Sherry A. Southerland, and Sonia Woodbury*, University of Utah; *Adam T. Johnston*, Weber State University

Importance of Reflection: Correspondence between Philosophy and Practice
This presentation addresses the under-examined reflection of instructors in higher education. One quest to reflect upon instructional practice is shared.

Presenter: *Eileen Carlton Parson,* University of North Carolina-Chapel Hill

1:20 - 2:20 p.m.	F 5.9	Laguna Ballroom

A Set of Recommended CORE ACTIVITIES for Science Education Doctoral Programs: Operationalizing the AETS Professional Knowledge Standard for Science Teacher Educators
A 1999 survey of science education doctoral programs demonstrated a lack of correlation of required skills and knowledge with the AETS professional knowledge standards for science teacher educators. A panel will propose a set of suggested CORE Activities for all science education doctoral programs. Participants are encouraged to respond.

Presenters: *Paul Jablon,* University of Massachusetts; *Robert Yager*, University of Iowa; *Norman Lederman*, University of Oregon; *William McComas*, University of Southern California

1:20 - 2:20 p.m.	F 5.10	Viejo Ballroom

Publications Committee Meeting

Julie Luft, Chair, AETS Publication Committee

2:40 - 3:40 p.m.	Coffee Break With AMTE	East Galleria

Friday Afternoon Concurrent Sessions 2:40-3:40 p.m.

2:40 - 3:40 p.m. **F 6.1** **San Marcos**

The Impact of Global School/University Partnerships on Science Teacher Enhancements
Participants will discuss the impact of cross-cultural school/university partnerships to develop web-based environmental science curricula on teacher enhancement, and some implications for school reform.

Presenters: *Julie Weisberg*, Agnes Scott College; *Jack Hassard*, Georgia State University; *Andrew Akakayan*, AL Herzen State Pedagogical University; *Tom Brown*, Kennesaw Mountain High School; *Kim Everett*, Ridgeland High School; *Marina Goryunova*, Experimental High School; *Brian Mumma*, Georgia State University; *Wayne Robinson*, Walker County Science Center; *Vital Sychev*, Russian State Hydrometeorological University

2:40 - 3:40 p.m. **F 6.2** **San Juan**

The 3 C's of Inquiry Learning and Teaching: Culture, Context, and Cues
A cross-case analysis study and its emergent recommendations for constructing environments using the 3C's to mitigate pre-service teacher resistance to inquiry will be presented.

Presenters: *Barbara S. Spector and Paschal Strong*, University of South Florida

Learning Together: A Collaboration between Researcher and Classroom Teacher using Inquiry-Based Instruction
The collaboration between a researcher and in-service teacher interested in enhancing their skills using inquiry-based science and earth science concepts will be presented.

Presenter: *James T. McDonald*, Purdue University

2:40 - 3:40 p.m. **F 6.3** **San Felipe**

Using the Web Based Integrated Science Environment (WISE) in Secondary Science Methods Courses
The efficacy of an Internet inquiry environment is described through case studies of individuals who interacted with the WISE environment in secondary science methods courses.

Presenter: *James M. Monaghan*, California State University, San Bernardino

Reactions to Constructivist Web-Based Learning of STS
Students' experiences with an interactive model for distance learning of STS consistent with reform goals and lessons learned to mitigate their anxieties will be presented.

Presenters: *Cherry O. Steffen, Barbara Spector, Ruth Burkett and Nina deVerteuil;* University of South Florida

2:40 - 3:40 p.m.	F 6.4	San Carlos

Students' Descriptions of Future Science Classroom Interactions and Environments
Elementary and secondary methods students' pre and post perceptions of themselves as science teachers are compared using a classroom description instrument. Students attend two different schools. This presentation will present information learned from students' classroom descriptions about the role of the teacher, the role of the student and the environment in which it takes place.

Presenters: *Robin Lee Harris,* Buffalo State College; *Patricia Gathman Nason,* Steven F. Austin State University

Explicit and Tacit Conceptions of Teaching and Learning Expressed by Students Experiencing a Second and Third Science Methods Course: Implications for the Structure of Pre-Service Science Teacher Education Programs
Students' semester ending research-based framework papers and oral defenses were analyzed to determine their conceptions of learning and teaching after their second and third semester of science methods.

Presenters: *Michael P. Clough,* Iowa State University; *Paul Numedahl,* Colorado College

2:40 - 3:40 p.m.	F 6.5	San Gabriel

Learning to Teach Science in Urban Schools
In this presentation, co-teaching is proposed as a viable model for teacher preparation and professional development of urban science teachers. An ethnography in which a new teacher assigned for a field experience in an urban high school enacted a curriculum that was culturally relevant for her African American students will be shared.

Presenters: *Kenneth Tobin*, University of Pennsylvania; *Wolff-Michael Roth*, University of Victoria; *Andrea Zimmerman*, University of Pennsylvania

Science Teacher Education as a Transformative Activity
In this paper, we describe an approach to science teacher education that is intended to be socially transformative to the contexts in which it occurs. We will describe an ongoing program of research in urban high schools in which we regard co-teaching as praxis that leads to a way of knowing about teaching and learning.

Presenters: *Gale Seiler and Kenneth Tobin,* University of Pennsylvania

2:40 - 3:40 p.m.	F 6.6	San Pedro

An Innovative Model for Developing Lateral Entry Secondary Science Teachers
NCTeach is a novel lateral entry approach to recruit qualified science professionals into the field of education.

Presenters: *William R. Veal and Dennis Kubasko,* University of North Carolina-Chapel Hill; *Warren DiBiase,* University of North Carolina-Charlotte; *David Boger,* North Carolina A&T State University; *Mark Latz*, University of North Carolina-Ashville; *Denise Gaskins,* Winston-Salem Forsyth County Schools; *Patricia LeGrand,* Gilford County Schools

2:40 - 3:40 p.m.	F 6.7	San Diego

What is Necessary to Include in a Science Methods Course for Teachers on Emergency Permits? The Role of the Feedback Portfolio
Using a feedback portfolio as the main data source, this study explores experiences found to be essential by secondary science teachers working on emergency permits.

Presenter: *Hedy Moscovici,* California State University, Dominguez Hills

Jumping onto the Portfolio Bandwagon: What Teachers Say About the Process
Analysis of goal documentation within graduate students' portfolios and their responses to an open-ended questionnaire provided insights into the value of the portfolio process.

Presenter: *Mary Stein,* Oakland University

3:45 - 5:00 p.m. **AETS KEYNOTE ADDRESS**
Costa Mesa and Balboa Ballroom

Using Technology from the Entertainment Industry to Facilitate Teaching

Keynote Speakers: *Dr. Stuart Sumida,* California State University, San Bernardino
Dr. Elizabeth Rega, Claremont Colleges

Dr. Sumida and Dr. Rega will discuss the use of media to illustrate science content in teacher education settings. Dr. Stuart Sumida is a specialist on the evolution of back-boned animals, and is consultant on various Disney films including Beauty and the Beast, Lion King, Pocahontas, Hercules, Mulan, Tarzan, and the upcoming Dinosaur and Fantasia 2000. Dr. Sumida's work in vertebrate paleontology has been featured in National Geographic. Dr. Elizabeth Rega has become the world's first choice for translating elements of human and primate anatomy to artists. She has worked on Pocahontas, Tarzan, Mulan Prince of Egypt, and Dinosaur.

5:00 p.m.	Ballroom Entrance

J. Paul Getty Museum

Pre-purchased ticket required. Board bus by Ballroom entrance. Bus leaves at 5:10 p.m.

Enjoy a night at the famous J.P. Getty Museum in Los Angeles. Highlights include Van Gough's Irises, and Monteil's Wheatstacks, housed in the architectural wonder designed by Richard Meier. Board bus by Ballroom entrance at 5:00 p.m., visit the Getty from 6:30 – 9:00, eating dinner at the museum's cafeteria. Fee of $15 includes transportation and entrance, but not dinner.

Saturday Morning

6:30 – 8:00 a.m.	**Continental Breakfast With AMTE**	**East Galleria**

Concurrent Sessions
8:00–9:00 a.m.

8:00 - 9:00 a.m.	S 1.1	San Marcos

Teaching Science and Telling Stories, Becoming an Elementary Teacher of Science
This symposium introduces Narrative Storytelling as a useful process for linking science learning experiences and developing understanding of one's "personalized nature of science.

Presenters: *Jo Anne Ollerenshaw,* University of Nebraska; *Julie A. Thomas,* Texas Tech University; *Juanita Jo Matkins*, University of Virginia

8:00 - 9:00 a.m.	S 1.2	San Juan

Nurturing Confidence in Preservice Elementary Science Teachers
Increase in pre-service elementary teacher confidence is correlated to development of knowledge in conceptual understanding, scientific habits of mind, and reflective practice.

Presenters: *Robert Bleicher* and *Nancy Romance,* Florida Atlantic University

Reflective Journal Writing paired with Inquiry-Based Science Instruction: Effects on Elementary Preservice Teachers' Science and Science Teaching Beliefs
Reflective journal writing influenced changed beliefs, toward science and science teaching, of elementary pre-service teachers enrolled in an Integrated Science course.

Presenters: *Glenda Love Bell,* Texas A & M University – Commerce

8:00 - 9:00 a.m.	S 1.3	San Felipe

Where are the Opportunities for Student Inquiry in High School Biology Textbooks? A Comparative Study
This content analysis of representative traditional versus standards-based high school biology textbooks found significant differences in opportunities for student inquiry.

Presenters: *Patricia Chandler,* The Citadel; *William H. Leonard,* Clemson University

Exploring Chemistry Teachers' Pedagogical Content Knowledge Regarding Moles
Focusing on mole concept an proportional reasoning, this study applied a "lesson plan" protocol to a group of teachers to examine pedagogical content knowledge.

Presenter: *Karen R. Dawkins,* University of North Carolina

8:00 - 9:00 a.m.	S 1.4	San Carlos

The Sisters in Science Program: A Three Year Analysis
Results of the last three years of Sisters in Science and next step recommendations on confronting equity in the science and mathematics classrooms will be presented.

Presenter(s): *Penny L. Hammrich* and *Beverly Livingston,* Temple University; *Greer Richardson,* LaSalle University

The Sisters in Science Program: Teachers' Reflections
Results over the last three years of teachers' reflections and dialogue toward teaching science and mathematics as they confront the issue of equitable practice.

Presenters: *Penny L. Hammrich* and *Beverly Livingston,* Temple University; *Greer Richardson,* LaSalle University

8:00 - 9:00 a.m.	S 1.5	San Gabriel

Creating a Common Vision for Reformed Teacher Education Program: Issues and Insights for Stakeholder Groups.
Factors influencing dynamics of interactions among varied stakeholders creating a common vision, illustrated by students in a doctoral class, will be presented.

Presenters: *Teresa Greely, Barbara S. Spector, Nina deVerteuil and* Cherry *Steffen*; University of South Florida

"Guess Who's Coming to Dinner" – An Education Reformer Confronts the Culture of Higher Education
The vision of reformed science education and teacher preparation at the University of Kansas and conflicts between the vision and the University culture.

Presenter: *James D. Ellis,* University of Kansas

8:00 - 9:00 a.m.	S 1.6	San Pedro

Teacher Learning and the Evolution of Science 690, a Distance Learning Course
The presentation of a case study of a graduate level, distance learning course followed by an interactive discussion of issues related to teaching remote students via technology.

Presenter: *Joan M. Whitworth,* Morehead State University

8:00 - 9:00 a.m.	S 1.7	San Diego

A New Song, A New Dance for Science Teaching and Learning: Making Sense of "Community" Through Narrative Forms of Inquiry
Narrative inquiry, as a way of understanding experience, allows science education researchers to live, tell, relive and retell stories as a means for exploring the evolution of science teaching and learning communities, in diverse settings. In this interactive workshop we will illustrate various forms of narrative inquiry including song, photoessay, poetry, murals and cases that have provided unique insights into "community" as a metaphor for science education reform.

Presenters: *Deborah Tippins,* University of Georgia; *Sharon E. Nicols* East Carolina University; *Purita P. Bilbao, Elvira L. Arellano, Tessie L. Barcenal, Merilin A. Castellano and Lourdes Morano,* West Visayas State University

8:00 - 9:00 a.m.	S 1.8	Capistrano Ballroom

Research Scientists and Teachers Collaborate to Bring Inquiry into the Classroom
First Step is an NSF funded program that has a teacher researching alongside a USDA/ARS scientist. Then they introduce inquiry activities into the teacher's classroom.

Presenters: *H. Craig Wilson and R.K. James,* Texas A & M University

8:00 - 9:00 a.m.	S 1.9	Laguna Ballroom

POSTER PRESENTATIONS — URBAN SCHOOLS

Learning to Teach Science across Cultural Boundaries
An investigation reporting upon efforts to bring issues of multicultural education and ethnic identity into the realm of graduate and undergraduate science methods courses.

Presenter: *John Settlage,* Cleveland State University

Science Teaching in Urban Schools
This exploration of science teaching in three urban schools show different interpretation of inquiry-based teaching and irrelevance of curricula for many students.

Presenter: *Anita Roychoudhury,* Miami University

Preparing Science Teachers for Urban Schools: Readings and Assignments
Reading and assignment for prospective urban secondary teachers in preliminary field-based course are shared. Rationale for assignments as well as student reactions are included.

Presenter: *Laura Henriques,* California State University, Long Beach

Challenges and Triumphs: Assessment of Urban Elementary Students Understanding of Science
Students in urban elementary settings often perform poorly on standardized tests and written exams. Drawings, concept maps, and multimedia products offer non-traditional assessment measures to determine conceptual understanding.

Presenters: *Amy Cox-Peterson,* California State University, Fullerton; *Joanne K. Olson,* Iowa State University

TEAM: Staff Development and Mentoring for Urban Elementary Teachers, Preservice Teachers, and Students
Project TEAM developed a partnership connecting urban elementary teachers with preservice teachers for the purpose of improving the quality of science instruction.

Presenters: *Ken King and Thomas Thompson,* Northern Illinois University

Readings for the Urban Science Educator
Readings addressing the strengths and challenges of teaching science in urban settings will be presented and their use will be discussed.

Presenters: *Sherry Southerland and Mary Burbank,* University of Utah

Motivating High School Students: A Complex Answer to a Simple Question
Teachers are often stymied when students ask, "Why do we need this stuff" We found an answer in combination of 4MAT, science literacy, and inquiry.

Presenter: *Lee Meadows,* University of Alabama at Birmingham

8:00 - 9:00 a.m. **S 1.10** **Viejo Ballroom**

Science as a Way of Knowing: Using Reader Response to Construct A Personal Understanding of Science Literature
We will present and model interactively, a literary technique called reader response, as a means of engaging students in the understanding and the creation of personal meaning of science literature.

Presenters: *Robert W. Blake Jr.* Towson University; *Robert W. Blake*, State University of New York

Saturday Morning Concurrent Sessions 9:20-10:20 a.m. — Math/Science Strand

9:20 - 10:20 a.m. **S 2.1** **Lido Room**

AETS/AMTE JOINT SESSION

NSF Initiatives in Mathematics and Science Teacher Enhancement and Instructional Materials Development
This session will describe current funding initiatives in NSF's Division of Elementary, Secondary and Informal Education. Program officers from the National Science Foundation will present an overview of current programs that have implications for teacher preparation in mathematics and science.

Presenters: *Kate Scantlebury, Jane Butler Kahle, John (Spud) Bradley and Anna Suarez,* National Science Foundation.

9:20 - 10:20 a.m. **S 2.2** **San Marcos**

Using a Project-Based Science (PBS) Approach with Education Students in the University Classroom: Early Reports of Successes, Challenges, and Opportunities for Research
Leaders in the area of project-based science will address a variety of issues of implementing such an approach in the university classroom with pre-service teachers.

Presenters: *Scott Lewis,* Florida International University; *Charlene Czerniak,* University of Toledo; *Jodi Haney,* Bowling Green State University; Joseph *Krajcik,* University of Michigan; *Andrew Lumpe,* Southern Illinois University; *George O'Brien,* Florida International University

9:20 - 10:20 a.m. **S 2.3** **San Juan**

Getting to the Fourth Year: A Study of the Practice of Beginning K-12 Science Teachers
Four presentations describing the instruments used and results obtained from the qualitative/quantitative study of over 90 beginning K-12 science teacher from across Minnesota.

Presenters: *George Davis, David Cline* and *Teresa Shume,* Minnesota State University Moorhead; *Patricia Simpson,* St Cloud State University

9:20 - 10:20 a.m. **S 2.4** **San Felipe**

The Use of Multiple Forms of Practitioner-Research in a Large-Scale Teacher Enhancement Project (Maryland Collaborative for Teacher Preparation)
Multiple forms of practitioner-research (college instructor case studies, teaching case studies, and mentor case studies) used in NSF-funded teacher enhancement program (CETP) are exhibited and discussed.

Presenter: *J. Randy McGinnis,* University of Maryland

Development of Constructivist Views of Teaching and Learning by M. Ed. Students in a Mathematics, Science & Technology Education Preservice Teacher Education Program
This research focused on the development of constructivist views of teaching and learning by M. Ed. Students in the MSAT (Mathematics, Science and Technology Education) teacher education program. Notions of learning identified as constructivist permeate all aspects of the MSAT M. Ed. Program (and the College of Education). Findings from this research will contribute significant findings relative to the impacts of the MSAT M. Ed. curriculum and, more generally, to the field of teacher education in terms of the relevance this research should have on (re)design of teacher education programs that assume contructivism as the basis for contemporary views of learning.

Presenters: *Youngsun Kwak and Michael Beeth,* The Ohio State University

9:20 - 10:20 a.m. S 2.5 San Carlos

New Horizons for Science Teacher Professional Development: Model-based Reasoning Using Information
This session provides examples and justification for model-based reasoning activities for science teachers using information technology via dynamic scientific computer models of phenomena. Both science and math activities will be included.

Presenters: *Cathleen C. Loving and Jane F. Schielack,* Texas A & M University

9:20 - 10:20 a.m. S 2.6 San Gabriel

AETS/AMTE JOINT SESSION
The CSMTP Report
In 1997, the National Research Council appointed a study committee to examine research on, and recommendations form national groups for the preparation of this country's science and mathematics teachers. The committee's co-chair and several of its members will share key findings and recommendations from the committee's recently released report, Educating Teachers of Science, Mathematics and Technology: New Practices for the New Millenium.

Presenters: *Herbert Brunkhorst,* California State University, San Bernardino; *Paul Kuerbis,* Colorado College; *Penny V. Gilmer*, Florida State University; *M. Gail Shroyer*, Kansas State University; *Larry Sowder,* San Diego State University

9:20 - 10:20 a.m. S 2.7 San Pedro

Sharing our Strategies: A New Role for Science Teachers
This paper describes the formulation, implementation, and evaluation of a new role for science teachers as conference presenters.

Presenters: *Pamela Fraser-Abder,* New York University; *Nina Leonhardt,* Suffolk County Community College

Sport Science: Using Sports as a Vehicle for Science Learning
The sport science program was conceived to increase the interest and literacy of middle school girls in science and mathematics through the vehicle of sports.

Presenters: *Penny L. Hammrich, Beverly Livingston and Tina Sloan Green,* Temple University; *Greer Richardson,* LaSalle University

9:20 - 10:20 a.m.	S 2.8	San Diego

Strategies Enabling Collaborative Teacher Teams to Develop and Implement Assessment of Student Understanding of Science
This three-year study identifies conceptual obstacles and enabling strategies for teams of teachers in grades 4-12 to develop and implement standards-based science and mathematics assessment.

Presenter: *Donna R. Sterling,* George Mason University

Using the Reform Teacher Observation Protocol (RTOP) Instrument as A Catalyst for Self-Reflective Change in Secondary Science Teaching
RTOP operationalizes an inquiry-oriented instructional enviornment. Twenty-eight secondary math and science teachers used it to assess their own and one another's teaching beliefs and practices.

Presenters: *Dan MacIsaac and Kathleen Falconer,* Northern Arizona University

9:20 - 10:20 a.m.	S 2.9	Capistrano Ballroom

Intelligent Television: The Annenberg/CPB Channel
Find out about **THE ANNENBERG/CPB CHANNEL,** carrying professional development programs and workshops for K-12 educators with an emphasis on math and science, and a variety of programs from popular PBS series. This free, satellite/Web service for schools, colleges, and communities broadcasts award winning, educational television 24 hours a day, 7 days a week.

Presenters: *Nancy Finkelstein* Harvard-Smithsonian Center for Astrophysics; *Gordon Lewis,* Annenberg/CPB Project

9:20 - 10:20 a.m.	S 2.10	Laguna Ballroom

Multiple Representations: Preparing Prospective Elementary Teachers to Teach Mathematics and Science from a Systems Approach
Presents an instructional model with classroom applications that reflect an integrated systems approach to mathematics and science lesson design through the use of multiple representations. This session is designed to incorporate interactive features of the model.

Presenters: *Carol L. Stuessy and Jennifer Parrott,* Texas A & M University

9:20 - 10:20 a.m.	S 2.11	Viejo Ballroom

Integrating Science and Mathematics: A Natural Connection or Strange Bedfellows?
Nature of science and nature of mathematics are compared and contrasted. Implications for the integration of science and mathematics are discussed.

Presenters: *Renee S. Schwartz,* Oregon State University; *Mary K. Gfeller,* Canton College; Norman *G. Lederman,* Oregon State University

The Bridges Project: Pairing Preservice and In-service Teachers for Professional Development in Science, Math, and Literacy Using Performance Assessment Tasks' Contexts
The implementation and results of the first year of a professional development project pairing preservice and in-service teachers in designing performance assessments in science and math.

Presenters: *Valarie L. Akerson and Amy McDuffie,* Washington State University

Saturday Morning
Concurrent Sessions
10:40-11:40 a.m.

10:40 - 11:40 a.m. | **S 3.1** | **San Marcos**

Strategies for Developing Pre and In-Service Elementary Science Teachers
Elementary Science Teacher Leadership (ESTL) is a teacher-enhancement project supported by the Exxon-Mobil Education Foundation. The project is providing pre and in service teacher educators with resources they can use to enhance the understanding of science and approaches to teaching for their students. Project experiences will be provided and attendees will receive an ESTL guide of their choice.

Presenters: *Herbert D. Thier and Marlene Thier,* Lawrence Hall of Science – University of California, Berkeley

Redesigning an Urban Science Methods Course
A secondary science methods course for urban teachers was redesigned to attempt to ameliorate the theory-practice gap. The program is described and its implications explored.

Presenters: *Gale Seiler and Kenneth Tobin,* University of Pennsylvania

10:40 - 11:40 a.m. | **S 3.2** | **San Juan**

The Learning Environments of Our Graduates' Classrooms: Perceptions of Teachers and Their Students
Comparisons of teacher and student perceptions of classroom learning environments are made with results from a study of recent graduates of Minnesota teacher education institutions.

Presenters: *Bruce Johnson*, University of Arizona; Jean *Hoff,* St. Cloud State University

Secondary Science Teacher Candidates' Beliefs and Practices
The beliefs regarding science teaching and learning of twenty-seven preservice teachers were examined via a survey and an open-ended questionnaire. These results were quantitatively compared to their classroom practices.

Presenter: *Deborah Waggett,* Castleton State College

10:40 - 11:40 a.m. | **S 3.3** | **San Felipe**

Using the Situated Laboratory Activity Instrument (SLAI) to Define Inquiry
This workshop will describe a small pilot study to assess the utility of using the Situated Laboratory Activity Instrument (SLAI) to define inquiry.

Presenters: *Lisa Dana and Paul Jablon,* University of Massachusetts - Lowell

10:40 - 11:40 a.m. **S 3.4** **San Carlos**

Teachers as Summer Scientific Researchers
This presentation describes an analysis of a summer program that partners secondary school science teachers with university research scientists. Factors for successful experiences are described.

Presenters: *Julie F. Westerlund, Dana M. Garcia and Joe R. Koke,* Southwest Texas State University; *Teresa A. Taylor,* Smithson Valley High School; *Diana Mason,* University of Texas at San Antonio

Science Internships: Do All the Pieces Fit? Part One... Student Views
A survey to assess students' conception of the research process and their views of the internship experience was completed during a 20 week internship program at Lawrence Livermore National Laboratory.

Presenter: *Phillip D. Wade,* Western Oregon University

10:40 - 11:40 a.m. **S 3.5** **San Gabriel**

Using Action Based Research Teams to Reform the College Science Curriculum for Teacher Preparation
Join us for a hands-on activity involving the development of action based research teams to impact the preparation of preservice teachers in science.

Presenters: *Gerald H. Krockover and Daniel P. Shepardson,* Purdue University

10:40 - 11:40 a.m. **S 3.6** **San Pedro**

Teaching Science in Urban Settings: An Interactive Symposium
This interactive panel will seek audience participation to discuss the challenges and successes of teaching science in urban settings.

Presenters: *Amy Cox-Peterson, Barbara Gonzalez and Nancy Pelaez,* California State University, Fullerton; *Laura Henriques,* California State University, Long Beach; *Diana Takenaga-Taga, Silvia Carranza, Amy Nigro and Rosa Nagaishi,* Los Angeles Unified Schools; *Ron Rita,* Long Beach Unified Schools

10:40 - 11:40 a.m. **S 3.7** **San Diego**

Teaching the Nature of Science Using Examples from Dinosaur Discovery and Interpretation
Examples from scientific investigations of dinosaurs provide teacher educators with a means to show how scientists' views change as new evidence surfaces.

Presenter: *Richard J. Batt,* Buffalo State College

Global Climate Change and the Nature of Science in an Elementary Science Methods Course
Explicit nature of science instruction and instruction in a controversial science topic led to gains in pre-service teachers' understandings of the nature of science.

Presenters: *Randy L. Bell and Juanita Jo Matkins,* University of Virginia

12:00 - 2:00 p.m. **AETS AWARDS LUNCHEON AND BUSINESS MEETING**
Capistrano, Laguna, Viejo Ballrooms

AETS Award Winners will be announced and the President will give the annual AETS President's Address. Ticket (included in registration packet) is required for lunch.

Saturday Afternoon Concurrent Sessions 2:15 – 3:15 p.m.

2:15 - 3:15 p.m. **S 4.1** **San Juan**

AETS 2001 Award Winning Paper Presentations

Deborah J. Tippins, Chair, AETS Awards Committee

2:15 - 3:15 p.m. **S 4.2** **San Marcos**

Look Who's Talking About Professional Development for Science Teachers? Center for Craniofacial Molecular Biology at the University of Southern California
This symposium discusses issues involved in a science teacher's professional development. Presenters are the lead teachers and administrators of a local school district, scientist and project director for a science research laboratory, and science educational researchers.

Presenters: *HsingChi A. Wang, Charles F. Shuler and Patricia Thompson, CCMB* University of Southern California; *Christopher Mihm and Carol Takemoto,* Los Angeles Unified School District; *Holly Henebry, Cecilia Fung and ChengChi Chang,* University of Southern California

2:15 - 3:15 p.m. **S 4.3** **San Felipe**

Constructivist Staff Development: Implications for Science Teacher Educators
This presented paper will focus on two different in-service programs that used a set of ten descriptors to determine the level of constructivist staff development implemented by the leaders.

Presenters: *Caroline Beller,* University of Arkansas; *Robert K. James,* Texas A & M University

Scientist-Teacher Partnerships: Epistemological Change Agents and Catalysts for Developing Transformational Classrooms
This grounded theory study investigated the interactions among a research scientist, a science teacher educator, and four high school science teachers in a field setting.

Presenter: *Robbie V. McCarty,* University of Oklahoma

2:15 - 3:15 p.m.	S 4.4	San Carlos

From Practice to Theory – Narrowing the Gap: First Year Science Teachers emerging from a Constructivist Science Education Program
This study explores the teaching practices of four first year science teachers, all graduating from an alternative pre-service program founded on constructivist principles. Through an interpretive design, the pedagogical perspectives and implicit theories of teaching were investigated in relation to the pre-service and first year teaching context.

Presenters: *Michael Dias and Jack Hassard,* Georgia State University

Changes of Teaching Philosophies of Four Science Teaching Interns during a Year – Long Internship
Science interns' teaching philosophies were recorded and analyzed three times during a year-long teaching internship. Changes in interns' teaching philosophies were noted.

Presenter: *Michael Wavering,* University of Arkansas

2:15 - 3:15 p.m.	S 4.5	San Gabriel

Integrating Technology Learning and Teaching Applications within an Elementary Science Methods Course
This symposium will present evidence that pre-service teachers are influenced to teach science with technology when effective teaching models are integrated in the science methods course.

Presenter: *Julie A. Thomas,* Texas Tech University

The Integration of Technology into Science Instruction
This methodological framework is centralized in five areas; planning, research, development, refinement, and implementation. These domains work as organizational frameworks for instruction, curriculum development, and implementation.

Presenter: *William H. Robertson,* Los Alamos National Laboratory

2:15 - 3:15 p.m.	S 4.6	San Pedro

Preparing Science Educators to Teach Students with Special Needs in Inclusive Settings
Project Inclusion provided financial support to general science educators by offering special education courses to include curricular modifications, discipline and collaboration strategies to facilitate the inclusion process.

Presenter: *Rita Combs-Richardson,* Southeastern Louisiana University

Dynamic Science Assessments
Capitalizing on the power of multiple intelligences, experience a wide variety of ways that students may demonstrate their knowledge of science.

Presenter: *Lisa M. Nyberg,* California State University, Fresno

2:15 - 3:15 p.m. | **S 4.7** | **San Diego**

Getting to Know AETS
This session will help all members (new and established) understand how AETS works and how individuals can become more involved. It will build on and support the Town Meetings.

Presenters: *Molly Weinburgh,* Georgia State University; *Julie Gess-Newsome,* Northern Arizona University

2:15 - 3:15 p.m. | **S 4.8** | **Capistrano Ballroom**

Prospective Biology Teachers' Understanding of Genetics Concepts
This study addressed the issue of whether prospective biology teachers possess an adequate understanding of some key concepts in genetics. Their understanding was explored by concept mapping activities.

Presenters: *Mustafa Cakir and Barbara Crawford,* Pennsylvania State University

Reconceptualizing a General Chemistry Curriculum
This session will provide an overview of Operation CHEM 1251. The project involves making major revisions to the general chemistry program at UNC Charlotte by developing and implementing a standards-based approach to instruction.

Presenters: *Warren J. DiBiase,* University of North Carolina; *Eugene P. Wagner II,* University of Pittsburgh

2:15 - 3:15 p.m. | **S 4.9** | **Laguna Ballroom**

Documenting, Interpreting and Evaluating Local Systemic Change: Core Requirements and Site-Specific Research Issues
This panel symposium will compare and contrast three projects and the difficulties and successes of their core evaluations. It will provide an opportunity to share research concerns, instruments, qualitative approaches and other strategies related to collecting valid and reliable data in a complex system of school districts, schools, classrooms and learning environments designed to promote specific types of inquiry–oriented science teaching and science literacy using NSF-funded science programs.

Presenters: *James A. Shymansky,* University of Missouri, St. Louis; *Charlene Czerniak,* University of Toledo; *Brian Hand,* Iowa State University; *Andrew Lumpe,* University of Southern Illinois; *Joanne K. Olson,* Iowa State University; *Larry Yore,* University of Victoria

2:15 - 3:15 p.m. | **S 4.10** | **Viejo Ballroom**

Problem Centered Teaching and Learning: A Physical Science Content Course for Teachers
This session describes a physical science course for teachers combining content with a problem-solving approach. Local situations are used to help future teachers prepare for anchored instruction that integrates math and science.

Presenters: *Bill Baird and Ralph Zee,* Auburn University

Constructing Investigations
Professionals in construction engineering, the building trades, and science education collaborated in a program that introduced construction problems as tools for learning science.

Presenters: *Lawrence B. Flick,* Oregon State University; *Walter Gamble,* Oregon Association of General Contractors

Saturday Afternoon Concurrent Sessions 3:35 – 4:35 p.m.

3:35 - 4:35 p.m. S 5.1 San Marcos

Preparing College Science Teachers for the Realities of Twenty-first Century Students and Colleges
Science doctoral students should be prepared to be college teachers. Heresy or reality? Four approaches to producing collegiate teachers (and researchers) will be discussed during this panel symposium.

Presenter(s): *Walter S. Smith*, Ball State University; *Norman G. Lederman,* Oregon State University; *Kathleen O'Sullivan,* San Francisco State University; *Arlene A. Russell,* University of California at Los Angeles.

3:35 - 4:35 p.m. S 5.2 San Juan

GLOBE as a Vehicle for Professional Development
GLOBE puts into practice authentic learning, student-scientist partnerships, and inquiry-based pedagogy. How are science teacher education programs incorporating GLOBE certification into their curricula?

Presenter: *Ruth Bombaugh,* Cleveland State University

An Evaluation of the Critical Thinking Curriculum Model (CTCM)
An evaluation of student attitudes towards science and technology and their learning of science content and problem solving skills in using the Critical Thinking Curriculum Model.

Presenter: *William Robertson,* Los Alamos National Laboratory

3:35 - 4:35 p.m. S 5.3 San Felipe

Evaluating the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT) Program
The ACEPT program has been effective in helping faculty develop reformed teaching methods, which lead to improved achievement and improved teaching performance among ACEPT graduates.

Presenters: *Anton E. Lawson and Michael D. Piburn*, Arizona State University

NSF Systemic Change Initiative Grant
A large NSF grant with mathematics, science and technology for K-5 schools in the Clark County School District in Las Vegas will be highlighted. Presenters will discuss the parameters of a standards-based, inquiry-oriented Mathematics and Science Enhancement Grant and the participation of the teachers and administrators in the eight collaborative learning center schools that are taking part.

Presenters: *William R. Speer,* University of Nevada – Las Vegas; *Christy Falba,* Clark County School District, Nevada

3:35 - 4:35 p.m.	S 5.4	San Carlos

Block Scheduling Science: Does It Help or Hinder?
This presentation covers the advantages and disadvantages of block scheduling in science teaching from a National Science Education Standards perspective. Achievement differences and teacher attitudes are included.

Presenters: *Donna L. Ross*, San Diego State University; *Julie F. Westerlund*, Southwest Texas State University

Attitude of Rural High School Students toward Science on the Block Schedule
This study found no change in high school students' attitudes toward science, contrary to previous findings of significant declines in traditional settings.

Presenters: *James Spellman and J. Steve Oliver*, University of Georgia

3:35 - 4:35 p.m.	S 5.5	San Gabriel

Developing Central Program Goals and Themes to Facilitate Effective Science Teacher Education
This interactive session will explore, discuss, and expand central goals for student learning that should underlie and guide the development and implementation of secondary science teacher education courses and programs. Teacher education strategies and organizing themes that can facilitate attainment of these goals will also be discussed.

Presenters: *Vincent N. Lunetta*, Pennsylvania State University; *Jeffrey W. Bloom*, Northern Arizona University

3:35 - 4:35 p.m.	S 5.6	San Pedro

Inclusive Pedagogy: Inviting All to Science Learning and Teaching
The presenters will critically examine the pedagogical approaches of science and science teacher education settings and illuminate the pathways and roadblocks to participation of traditionally marginalized groups.

Presenters: *Kathleen S. Davis*, University of Massachusetts, Amherst; *Joan M. Whitworth*, Morehead State University; *Helen L. Gibson*, Holyoke Public Schools; *Tarin Weiss*, University of Massachusetts, Amherst.

3:35 - 4:35 p.m.	S 5.7	San Diego

Daughters with Disabilities: Professional Development Models to Reframe Science, Math and Technology Education
This presentation describes inservice/preservice training activities from the Daughters with Disabilities program. Participants will explore gender-free, culturally relevant science, math, and technology resources.

Presenters: *Penny Hammrich, Lynda Price and Graciela Slesaransky-Poe*, Temple University

The Levels of Accessibility Matrix System for Determining Appropriateness of Hands-on Science Activities for Students with Disabilities
Preliminary work will be reported on The Levels of Accessibility Matrix system for analyzing the nature of hands-on science activities for inclusion of students with disabilities.

Presenters: *E. Barbara Klemm and Joseph Laszio*, University of Hawaii

3:35 - 4:35 p.m.	S 5.8	Capistrano Ballroom

The Effect of an After-School Science Program on Middle School Female Students' Attitudes Toward Science and Mathematics
This study examined the implementation of an after-school science program on a group of female, minority students' attitudes towards science and mathematics.

Presenter: *Maria M. Ferreira,* Wayne State University

Science and Mathematics Professional Development at a Small Liberal Arts University: Effects on Content Knowledge, Teacher Confidence, and Student Achievement
This study examines a professional development program with middle school science and mathematics teachers from a large urban district and its effects on teachers' content knowledge, confidence in teaching these subjects, and impact on classroom and students.

Presenter: *Cynthia H. Geer,* Xavier University

3:35 - 4:35 p.m.	S 5.9	Laguna Ballroom

Science and Mathematics Methods: Integrating Activities and Content
A collaboration between middle grade science and mathematics methods courses is discussed that emphasizes the connections between the courses. Outdoor settings and activities, and student development of an interdisciplinary unit are utilized.

Presenters: *Martha Schriver,* Georgia Southern University; *Gregory Chamblee,* Georgia Southern University

3:35 - 4:35 p.m.	S 5.10	Viejo Ballroom

Making *A Private Universe* Public: Multi-media Materials as a Springboard for Expanding Curriculum Development, In-service, and Pre-service Science and Mathematics Education
A variety of mathematics and science educators will build on previous AETS presentations and share the many ways they use multi-media materials in curriculum and instruction.

Presenters: *Natalie S. Barman, Charles R. Barman, Michael R. Cohen, Beatriz D'Ambrosio and Sue Mau,* IUPUI; *Dana Riley Black,* University of Washington; *Nancy Finkelstein,* Harvard-Smithsonian Center for Astrophysics; *Anita Greenwood,* University of Massachusetts, Lowell; *Philip M. Sadler,* Harvard University

Saturday Afternoon Concurrent Sessions 4:55 – 5:55 p.m.

4:55 - 5:55 p.m.	S 6.1	San Marcos

What Are We Supposed to See? Visual Perception of Small Aquatic Animals by Non-Science Majors and Biology Students; Comparisons, Correlations and Implications
This study aims to evaluate novice biologists' abilities to visually perceive small living specimens in artificial ecosystems and compares visual ability of novices with that of experienced field biologists. Some specific correlations are suggested and explanations for observed patterns are explored.

Presenter: *Robert Day,* Ohio State University

Crime in Color; Constructivism by Chromatography
A crime has been committed. Chromatography activities arranged in a foundational mode, applied within a constructivist frame facilitate learners to transcend the ZPD, and the crime is solved. This presentation includes a set of five activities dealing with chromatography.

Presenter: *Joseph R. Laszio,* University of Hawaii

4:55 - 5:55 p.m.	S 6.2	San Juan

Lessons Learned by Preservice Teachers from Doing Research: Implications for Science Education Programs
This presentation will focus on the proposed benefits of having pre-service teachers participate in misconception research by focusing on their alternative conceptions, the value of questioning techniques, and the complex nature of teaching.

Presenters: *Jamie D. Stockton,* DePauw University; *Charles R. Barman and Natalie S. Barman,* IUPUI

Standards-based Teacher Licensure Programs and Their Impact on Teacher Education Programs
Many states have created INTASC based standards licensure programs. Join your colleagues in this interactive session to discuss benefits and consequences of these programs and share strategies for success.

Presenter: *Patricia R. Simpson,* St. Cloud State University

4:55 - 5:55 p.m.	S 6.3	San Felipe

Building Collaboratives for Inquiry: Goals, Glitches, and Glue
Panelists will discuss the establishment of teacher-scientist collaboratives that aim to improve teachers' knowledge about and abilities to teach science as inquiry.

Presenters: *Renee S. Schwartz,* Oregon State University; *Norman G. Lederman,* Oregon State University; *Julie Westerlund,* Southwest Texas State University; *Penny J. Gilmer,* Florida State University; *Lori Hahn,* Florida State University; *Norman Herr,* California State University, Northridge

4:55 - 5:55 p.m.	S 6.4	San Carlos

The Effects of Group Collaboration and Facilitation for High School and Middle School Science Teachers Attempting NBPTS Certification in 1998-99
In this study, 100% of the high school and middle school science teacher candidates' participation in the 1998-99 Board of Professional Teaching Standards certification process were surveyed. Results based on the 60% return rate revealed some interesting findings.

Presenter: *Sharon Lynch,* The George Washington University

National Boards for Professional Teaching Standards: Raising the Bar
In this interactive session, we will share how the National Board for Professional Teaching Standards (NBPTS) certification process inspired us to raise the level of scientific thinking for our students as we led them through a higher level, more meaningful curriculum. The NBPTS is growing in popularity and is a true form of professional development for accomplished teachers who desire to hold themselves to the highest standards.

Presenters: *Kristine Quinn and Hollis Cruse;* California State University, Fullerton

4:55 - 5:55 p.m. | **S 6.5** | **San Gabriel**

A Correlation of Academic Background and Religious Beliefs with Preservice Teachers' Self-Efficacy for Teaching Evolution
Preservice teachers' undergraduate academic science background and their religious beliefs are correlated to self-efficacy for teaching evolution based on a modified STEBI-B instrument.

Presenter: *Suzanne Shaw Drummer,* Ohio State University

Redesign in Science Teacher Preparation
This interactive session will examine the diverse views on science teacher preparation and will articulate a list of principles that further participants' collaborative efforts to redesign science teacher preparation.

Presenters: *Michael E. Beeth, Gyoungho Lee and Hyeoksoon Kwon,* Ohio State University

4:55 - 5:55 p.m. | **S 6.6** | **San Pedro**

Intersections of Sexuality Knowledge and Practice in Science Teacher Education
This symposium examines the effects of cultural norms of (hetero) sexuality in science teacher education and paths to more empowering understandings of self and science. Our papers illustrate ways that sexuality does matter in science teacher education and how individuals' identities and understandings of science are constituted in part along the intersections of sexuality and knowledge.

Presenters: *Steve Fifield,* University of Delaware; *John Mascazine,* Ohio State University; *Connie Nobles,* Southeastern Louisiana University; *Anne-Marie Scholer,* Endicott College

4:55 - 5:55 p.m. | **S 6.7** | **San Diego**

Determining How to Use Graphic Organizers in a Sixth Grade Science Classroom
This project focused on determining how to use three specific graphic organizers in a sixth-grade science classroom during a student teaching experience.

Presenters: *Erik O. Stine and Valarie L. Akerson,* Washington State University

Drawing on Their Understanding: Using Illustrations to Invoke Deeper Thinking About Plants
Analysis of young children's science drawings provides insights into their conceptual understandings. The use of drawings as a means for understanding children's beliefs will be examined.

Presenters: *Mary Stein and Shannon McNair,* Oakland University

4:55 - 5:55 p.m. | **S 6.8** | **Capistrano Ballroom**

Moving a School District toward Constructivism and the National Science Education Standards: A Follow-Up Study – How Successful Were We?
An Evaluation of a school district's three-phrase curriculum/staff development project to develop a program committed to teaching science for understanding – one year after its "completion".

Presenter: *Valerie Keeling Olness,* Augustana College

Fostering Teacher Development: A New Approach to Early Childhood Science Teacher Education?
An exploration of how science methods coursework and practica experiences can be structured to foster the professional development of prospective early childhood science teachers.

Presenter: *Amy B. Palmeri,* Vanderbilt University

4:55 - 5:55 p.m.	S 6.9	Laguna Ballroom

Discovering Modern Science in Ancient Nature Legends
Nature legends are gentle teachers that can capture attention and stimulate curiosity. This session will present ways to discover the meaningful connections to science within them.

Presenter: *Candace R. Miller,* The Ohio State University at Lima

4:55 - 5:55 p.m.	S 6.10	Viejo Ballroom

University Science Majors in Collaborative Partnerships with Elementary Teachers: Inquiry Based Teaching and Learning
Experiences using graduate and upper division, undergraduate science majors to assist elementary teachers in their development and delivery of kit-based science lessons will be shared.

Presenters: *Donna L. Ross, Cheryl L. Mason and Walt Oechel,* San Diego State University; *Nancy Taylor,* San Diego County Office of Education

Portraits of Partnership: Case Studies of College Science Students with Teachers in Urban Elementary Classrooms
This study describes the motivations, roles taken, and impact of long-term science teaching partnerships on the development of teacher and undergraduate participants in two different cases.

Presenter: *Camille A. Goebel,* Emory University

4:55 – 5:55 p.m.	S 6.11	Mesa Verde Room

AETS 2002 Planning Meeting
All AETS members are invited to attend this planning meeting for the 2002 AETS conference.
Warren DiBiase, Chair, AETS 2002 International Conference Committee

7:30 - 9:30 p.m.	S 7.1	Santa Ana Room

WISE Dessert Function

All AETS members are invited to attend this Women in Science Education get-together. (Tickets must be purchased prior to the event.)

Sunday Morning

6:30 - 8:00 a.m. | **Continental Breakfast** | **East Galleria**

8:00 - 12:00 Noon | **AETS Board Meeting** | **China Cove Room**

Sunday Morning
Concurrent Sessions
8:00 – 9:00 a.m.

8:00 - 9:00 a.m. | **Su 1.1** | **San Marcos**

Design and Implementation of a Science Teacher Preparation Program in a College of Science
In this panel symposium presentation, we will describe the new Science Teacher Preparation Program in the College of Science at the University of Arizona.

Presenters: *Ingrid Novodvorsky, Richard Greenberg, Mary McCaslin, Vicente Talanquer and Debra Tomanek,* University of Arizona

8:00 - 9:00 a.m. | **Su 1.2** | **San Juan**

"Just in Time": An Alternative Pathway to Teacher Preparation
The presenter will share background on alternative licensure programs, challenges during the design of APT, the early successes, and the issues and problems yet to be resolved. Advice on the evaluation of the program will be sought from session participants.

Presenter: *Camille L. Wainwright,* Pacific University of Oregon

An Exodus of Gifted Teachers: Science Teachers Take Alternatives to Teaching
This study examines three beginning science teachers who left teaching. The reasons they left, where they went, and how they compare nationally will be discussed.

Presenters: *Nancy Patterson, Gill Roehrig and Julie Luft,* University of Arizona

8:00 - 9:00 a.m. | **Su 1.3** | **San Felipe**

Fostering Science Education Renewal by Bridging a University's Scientific Culture with a K12 Culture
This presentation introduces the mechanisms a Research-1 University is establishing in order to actualize its newly established core mission of supporting K12 science education.

Presenter: *Dana Riley Black,* University of Washington

What Constitutes Academic Rigor? Framing an Opening Discussion Regarding the Criteria for Evaluating Academic Rigor of State Standards and Local Curricula in K-16 Science Education
Conflicting claims of rigor in science education standards and curricula are being used in the scientific and public realms. A simplified model rubric for analyzing rigor is proposed, based on the "National Science Education Standards".

Presenter: *Bonnie J. Brunkhorst,* California State University, San Bernardino

8:00 - 9:00 a.m.	**Su 1.4**	**San Carlos**

Museum Outreach: Inclusion of Professional Development to Enhance Student Learning
This case study explores methods by which in-services can meet the diverse need of elementary teachers and improve student understanding in museum sponsored science programs.

Presenter: *Sarah S. Thompson,* Natural History Museum of Los Angeles County

Grinding Stones and Dinosaur Bones: Informal Institutions as In-service Providers
Participants of an in-service at a natural history museum reported significant gains in content and pedagogical knowledge and rated the program more helpful than traditional in-services.

Presenter: *Leah M. Melber,* Natural History Museum of Los Angeles County

8:00 - 9:00 a.m.	**Su 1.5**	**San Gabriel**

Issues in the Preparation of Teachers to Face the Challenge of the Black-White Achievement Gap in Science
The persistent achievement gap between White students and African-American students is a national concern. We use the results from a year long study of science classrooms to discuss how culturally responsive pedagogy may be a potent way to address and minimize this achievement differential.

Presenters: *Obed Norman,* Washington State University, *Charles R. Ault, Jr.,* Lewis & Clark College

8:00 - 9:00 a.m.	**Su 1.6**	**San Pedro**

Science Teaching Self-Efficacy Beliefs: A Discussion of Preservice, In-service, and Measurement Issues
This presentation will be conducted in response to updated surveys of the AETS and NARST membership regarding interest from a group of researchers interested in science teaching self-efficacy. This survey was last administered to colleagues in the spring of 1994. This informal group will focus on the topic of science teaching self-efficacy.

Presenters: *Larry G. Enochs,* Oregon State University; *Iris Riggs,* California State University at San Bernardino; *Charlene Czerniak,* University of Toledo; *Andrew Lumpe,* Southern Illinois University – Carbondale; *Margaret Gail Shroyer,* Kansas State University; *Jodi Haney,* Bowling Green State University

Improving Girls' Self-Efficacy Toward Science
This action research project focused on implementing teaching strategies geared toward increasing fourth-grade girls' self-efficacy toward science. Results from the study will be discussed.

Presenters: *Michelle Bohrman and Valarie Akerson,* Washington State University

8:00 - 9:00 a.m. | **Su 1.7** | **San Diego**

Stories from the Field: Challenges of Science Teaching/Learning through Interdisciplinary Approaches
In this novel format session, we will examine dilemmas, methods, students, and teachers using interdisciplinary approaches that they encounter when trying to enhance science learning.

Presenters: *Katherine C. Wieseman,* Western State College; *Hedy Moscovici,* California State University, Dominguez Hills; *Maureen M. McMahon,* University of California -Davis; *Turtle Moore; Esme McCarthy; Jill van Tiel,* Western State College

8:00 - 9:00 a.m. | **Su 1.8** | **Capistrano Ballroom**

The Genesis of Science Teaching in the Elementary School: The Influence of Student Teaching
This investigation examined the impact of the student teaching semester on pre-service elementary teachers' personal efficacy beliefs and outcome expectancy beliefs in science teaching.

Presenter: *Lee A. Plourde,* Central Washington University

Impacts of Informal Science Education on In-service Elementary Teachers
This paper investigates in-service teachers' learning experiences in developing and implementing an inquiry-based "mini-research project" on informal science education settings, while taking graduate science education courses.

Presenter: *Isabel N. Quita,* San Francisco State University

8:00 - 9:00 a.m. | **Su 1.9** | **Laguna Ballroom**

I.M.P.A.C.T. : Research toward Improving Multi-Disciplinary Performance and Collaborative Teamwork
This session presents research results to identify the skills, knowledge, and resources needed in order to effectively and successfully utilize group projects in classroom curricula.

Presenters: *Aimee L. Govett and L. Jean Henry,* University of Nevada, Las Vegas

Goals 2000 & Action Research: A Viable Plan for Teachers
This session will discuss the Goals 2000 research project for Lane County School District in Eugene, Oregon. The project was based on Action Research conducted by the teachers. Discussion of the survey results of this program, as well as a discussion of Action Research as a legitimate form of research, will be discussed.

Presenters: *David T. Crowther,* University of Nevada, Reno; *Norman G. Lederman,* Oregon State University; *Bob Curtis,* Lane County School District; *John R. Cannon,* University of Nevada, Reno

8:00 - 9:00 a.m. | **Su 1.10** | **Viejo Ballroom**

Using Many Models of Teaching to Meet Students' Needs
Science methods courses at a university present many models of teaching, described by Bruce Joyce, especially to motivate students and to meet their needs.

Presenter(s): *David R. Stronck,* California State University, Hayward

Three Elementary Student Teachers' Conceptions of Teaching Science as Revealed by Their Concept Maps
This study compares the changes in three non-western European-American student teachers' concept maps on the subject of teaching science to adolescent English language learners compared to their western European-American peers over the course of a one year science teacher education program.

Presenter: *J. Richard Pomeroy,* University of California, Davis

Sunday Morning Concurrent Sessions 9:20 – 10:20 a.m.

9:20 - 10:20 a.m.	Su 2.1	San Marcos

Assessing Understanding in Chemistry with Calibrated Peer Review
An Internet-delivered instructional and assessment tool with a library component. Calibrated Peer Review (CPR) through peer evaluation of writing promotes critical understanding in chemistry.

Presenter: *Barbara L. Gonzalez,* California State University, Fullerton

Calibrated Peer Review in General Education Undergraduate Human Physiology
Calibrated Peer Review reveals student misconceptions, links modern scientific research to everyday experience, and deepens student learning of basic concepts in general education human physiology.

Presenter: *Nancy J. Pelaez,* California State University, Fullerton

9:20 - 10:20 a.m.	Su 2.2	San Juan

The Biological Basis for Gender Based Differences in Web-Based "Discussions" and Assessment
This presentation discusses why elimination of appearance or voice pitch cues does not automatically create equity for women in science education communication.

Presenter: *Ruth S. Burkett,* University of South Florida

9:20 - 10:20 a.m.	Su 2.3	San Felipe

Constraints to the Implementation of Constructivist Science Lessons
This paper identifies the constraints that impeded participants of a two-year induction program from implementing student centered science education reforms, such as "science as inquiry".

Presenters: *Gillian Roehrig, Nancy Patterson, Steve Uyeda and Julie Luft,* University of Arizona

Science Teachers' Diagnosis and Understanding of Students' Preconceptions
This study focused on how science teachers attempt to diagnose students' preconceptions in the classroom and the understanding the teachers have about these preconceptions.

Presenter: *Judith A. Morrison,* Washington State University

9:20 - 10:20 a.m.	Su 2.4	San Carlos

Science Teacher Education Beyond the Classroom: A Model Program for Incorporating Informal Environments in Science Teacher Education
This session will discuss *Strategies in Informal Science Learning*, a course designed to assist teachers in understanding the rationales for and implications of science teaching in informal environments.

Presenter *William F. McComas*, University of Southern California

Worksheets, Museums and Teacher Agendas: Creating a Learning Experience
Teacher generated museum worksheets were examined to gain a clearer picture of learning expectations and teacher agendas for class visits to a natural history museum.

Presenter: *James Kisiel*, Natural History Museum of Los Angeles County

9:20 - 10:20 a.m.	Su 2.5	San Gabriel

From the Outer Planets to the Inner City: Linking NASA to Urban Education Initiatives in the High School Science Classroom
Modeling how National Aeronautics and Space Administration (NASA) space exploration project teams do science sparks innovative teaching of science and the nature of science to inner city high school students.

Presenter: *Richard Shope*, NASA- Jet Propulsion Laboratory; *Lloyd Chapman*

9:20 - 10:20 a.m.	Su 2.6	San Pedro

Improving University Science and Engineering Instruction – A Case Study of an Environmental Engineering Lab Course
This session discusses research results related to improving a college environmental engineering professor's teaching of a lab course.

Presenters: *Valarie L. Akerson, Victor F. Medina* and *Nina Wang*, Washington State University

9:20 - 10:20 a.m.	Su 2.7	San Diego

Content-Based Professional Development: A Video Exploration
Participants will view and discuss excerpts of mathematics and science content-based professional development in action, exploring the issue of how a given professional development strategy supports participants' learning mathematics and/or science content.

Presenter: *Jerome Shaw and Cathy Carroll*, WestEd

9:20 - 10:20 a.m.	Su 2.8	Capistrano Ballroom

GIS in Education
Geographic Information Systems (GIS) are making their way into classrooms across the continent. With ArcView or ArcVoyager GIS software from ESRI and free data from the Internet, teachers can explore the world. Participants will receive a free CD containing ArcVoyager Special Edition GIS software, lessons, and data.

Presenters: *Charlie Fitzpatrick and the ESRI Education Team*, ESRI Schools and Libraries

9:20 - 10:20 a.m. | **Su 2.9** | **Laguna Ballroom**

CSU – Creating an Integrated Elementary Teacher Education Program: The Response of Nine CSU Campuses

The California State University system was mandated to develop programs to curtail the state's teacher shortage. Nine campuses share the impact of this mandate on elementary science teacher preparation.

Presenters: *Laura Henriques and Alan Colburn,* CSU Long Beach; *Amy Cox-Peterson, Teresa Crawford, Barbara Gonzalez and Nancy Pelaez,* CSU Fullerton; *Hedy Moscovici and John McGowan*, CSU Dominguez Hills; *Barbara Hawkins*, CSU Northridge; *Barbara Burke and Ed Walton,* Cal Poly Pomona; *Bonnie Brunkhorst and Herbert Brunkhorst*, CSU San Bernardino; *Kathy Norman and Robert Yamashita*, CSU San Marcos; *Cheryl L. Mason and Donna L. Ross*, San Diego State University; *Isabel Quita*, San Francisco State University

9:20 - 10:20 a.m. | **Su 2.10** | **Viejo Ballroom**

Hands-on Science with TI Technology

Come play with TI Technology for the science classroom. We will conduct a simple experiment with the CBL 2 data collection device, and explore new science software for the TI-83 Plus graphing calculator.

Presenter: *Eren Koont,* Texas Instruments, Inc.

AETS Presidents:

1932-34	S. Ralph Powers	1971-72	Paul Westmeyer
1935-36	John C. Johnson	1972-73	Ronald D. Anderson
1936-38	W.L. Kikenberry	1973-74	Robert E. Yager
1938-40	E. Laurence Palmer	1974-75	David P. Butts
1940-41	Earl R. Glenn	1975-76	Jacob Blankenship
1941-45	Anna M. Gemmill	1976-77	Patricia Blosser
1946-47	Victor L. Crowell	1977-78	David H. Ost
1947-48	Ellis Haworth	1978-79	John Schaff
1948-49	H. Emmett Brown	1979-80	Ertle Thompson
1949-50	John Read	1980-81	Hans Anderson
1950-51	George Haupt	1981-82	Jerry C. Horn
1951-52	Robert Cooper	1982-83	James P. Barufaldi
1952-53	Rose Lammel	1983-84	Ron W. Cleminson
1953-54	G.P. Cahoon	1984-85	Thomas P. Evans
1954-55	Ned Bryan	1985-86	Marvin Druger
1955-56	John Wells	1986-87	Robert K. James
1956-57	Robert Wickware	1987-88	Joyce Swartney
1957-58	June Lewis	1988-89	William C. Ritz
1958-59	George Zimmer	1989-90	Floyd Mattheis
1959-60	Harold Tannenbaum	1990-91	Gwendolyn Henderson
1960-61	Herbert Schwartz	1991-92	Roger Olstad
1961-62	Fletcher Watson	1992-93	Catherine G. Yeotis
1962-63	Willard Jacobson	1993-94	Peter A. Rubba
1963-64	R. Will Burnett	1994-95	Norman Lederman
1964-65	Herbert Smith	1995-96	Jim Ellis
1965-66	Ralph Lefler	1996-97	Paul Kuerbis
1966-67	Edward Victor	1997-98	William Baird
1967-68	Sylvan Mickelson	1998-99	Larry Flick
1968-69	Stephen Winter	1999-00	John Staver
1969-70	Eugene Lee	2000-01	Julie Gess-Newsome
1970-71	John Montean	2001-02	Molly Weinburgh

AETS AWARDS:

Outstanding Science Educator of the Year

1979	Roger W. Bybee, BSCS
1980	Anton Lawson, Arizona State University
1983	William R. Capie, University of Georgia
1985	James Dudley Herron, Purdue University
1986	Charles R. Coble, East Caroline University
1987	John Penick, University of Iowa
1988	James Barufaldi, University of Texas
1989	Lawrence F. Lowery, University of California
1990	William C. Kyle, Jr., Purdue University
1991	Barry Fraser, Curtin University of Technology, Australia
1993	Cheryl Mason, San Diego State University
1994	Patricia Simmons, University of Georgia
1995	J. Preston Prather, University of Virginia
1996	Sandra Abell, Purdue University
1997	Bonnie Shapiro, University of Calgary
1998	William F. McComas, University of Southern California
1999	Patricia Simpson, St. Cloud State University
2000	Wolf-Michael Roth, University of Victoria
2001	John Settlage, Cleveland State University

Outstanding Mentor Award

1997	John Penick, University of Iowa
1998	Hans Anderson, Indiana University
1999	Norman Lederman, Oregon State University'
2000	Robert K. James, Texas A & M University
2001	Robert E. Yager, University of Iowa

Implication of Research for Educational Practice

1981 Wait-time and Learning in Science
Kevin Tobin, Western Australia Institute of Technology and
William Capie, University of Georgia

1983 The Disadvantaged Majority: Science Education for Women
Jane Butler Kahle, Purdue University

1984 Training Science Teachers to Use Better Teaching Strategies
Russell H. Yeany and Michael J. Padilla, University of Georgia

1985 Using Research to Improve Science Teaching Practice
Kenneth Tobin, Western Australian Institute of Technology

1986 Active Teaching for Higher Cognitive Level Learning in Science
Kenneth Tobin, William Capie, and Antonio Bettencourt, University of Georgia

1987 Training Teachers to Teach Effectively in the Laboratory
Pinchas Tamir, The Hebrew University

1988 What Can Be Learned From Investigations of Exemplary Teaching Practice
Kenneth Tobin, Florida State University

1989 Visual/Spatial Thinking: An Essential Element of Elementary Science
Alan J. McCormack, San Diego State University

1990 Helping Students Learn How to Learn: A View form a Teacher-Researcher
Joe Novak, Cornell University

1991 An Expanded View of the Learning Cycle: New Ideas About an Effective Teaching Strategy
Charles R. Barman, Indiana University

1992 Teacher Development in Microcomputer Usage in K-12 Science
James D. Ellis, BSCS

1993 Understanding and Assessing Hands-On Science
Larry Flick, Washington State University

1994 Teaching Evolution: Designing Successful Instruction
Lawrence Scharmann, Kansas State University

1995 Using Visits to Interactive Science and Technology Centers, Museums, Aquaria and Zoos to Promote Learning in Science
Leonie Rennie and Terrence McClafferty

1996 General Biology: Creating a Positive Learning Environment for Elementary Education Majors
Larry Scharrman and Ann Stanheim-Smith, Kansas State University

1997 Empowering Science Teachers: A Model for Professional Development
Ann Howe, University of North Carolina at Raleigh and
Harriet Stubbs, North Carolina State University

1999 A Dynamical Systems Based Model of Conceptual Change
Andrew Hurford, Haskell Indian Nations University

2000 Teachers and Technology: A Case Study from an Implementation Project, Myra Halpin and Ann Howe, North Carolina School of Science and Mathematics, and North Carolina State University

2001 Visual/Spatial Thinking: A Forgotten Fundamental for School Science Programs, Alan J. McCormack and Cheryl L. Mason, San Diego State University

Innovation in Teaching Science Teachers

1990 A Reflective Approach to Science Methods Courses for Preservice Elementary Teachers
Dorothy Rosenthal, California State University – Long Beach

1991 Enhancing Science and Mathematics Teaching
Kenneth Tobin, Nancy Davis, Kenneth Shaw, and Elizabeth Jakubowski, Florida State University

1992 The Learning Cycle as a Model for the Design of Science Teacher Preservice and Inservice Education
Peter Rubba, Pennsylvania State University

1993 Reconstructing Science Teacher Education Within Communities of Learners
Deborah Tippins, University of Georgia
Kenneth Tobin, Florida State University
Sherrie Nichols, East Carolina State University

1995 Science for Early Adolescence Teachers (Science FEAT): A Program for Research and Learning
Samuel Spiegel, Angelo Collins, and Penny Gilmer, Florida State University

1996 An Innovative Model for Collaborative Reform in Elementary School Science Teaching
M. Gail Shroyer, Emmett Wright, and Linda Ramey-Gassert, Kansas State Univ.

1997 Reconceptualizing the Elementary Science Methods Course Using Reflective Orientation
Sandra Abell and Lynn Bryan, Purdue University

1998 What Science Education Standards Say: Implications for Teacher Education
Penny Hammrich, Temple University

2000 Professional Development Programs for Elementary Science Teachers: An Analysis of Teacher Self-Efficacy Beliefs and The Professional Development Model
Tracy J. Posnanski, University of Wisconsin-Milwaukee

2001 Empowering Teachers as Researchers and Inquirers
Anne M. (Amy) Cox-Peterson, California State University, Fullerton

Emeritus Awards

N. Eldred Bingham
University of Florida

Clarence Boeck
University of Minnesota

R. Will Burnett
University of Illinois

Gerald Craig
Teachers College, Columbia University

Paul Dehart Hurd
Stanford University

Addison Lee
University of Texas

Ralph Lefler
Purdue University

Harold Tannenbaum
Hunter College

Edward Victor
Northwestern University

Milton O. Pella
University of Wisconsin

Fletcher Watson
Harvard University

Fred Fox
Oregon State University

Herbert Smith
Colorado State University

Alfred De Vito
Purdue University

Robert W. Howe
Ohio State University

Willard Jacobson
Teachers College, Columbia University

Steven Winter
Tufts University

Stanley Helgeson
Ohio State University

Pinchas Tamir
Hebrew University

Marvin Druger
Syracuse University

Nasrine Adibe
Dowling College

Roger Olstad
University of Washington

Hans Anderson
Indiana University

AETS

2001 Annual Conference Proceedings Guidelines

(also available at http://www.aets.unr.edu/)

These guidelines differ in a number of respects from those for past AETS Proceedings.
AETS members are encouraged to review them carefully.
The bolded areas note changes in the guidelines from 2000.
Please contact Pete Rubba with any questions (par4@psu.edu).

Papers and summaries of presentations made at the 2001 AETS Annual Conference can be submitted for inclusion in the 2001 AETS Conference Proceedings. The Proceedings again will be published as an ERIC document through the ERIC Clearinghouse for Science, Mathematics and Environmental Education, with microfiche and hard copies available through ERIC. The 2001 Proceedings also will be available on the AETS World Wide Web Site (http://www.aets.unr.edu/), as are the 1996, 1997 1998, 1999 and 2000 Proceedings. Pete Rubba, Jim Rye, Warren DiBiase, and Barbara Crawford will edit the 2001 Proceedings. Details are provided below.

* Papers presented at and summaries of presentations made at the 2001 AETS Annual Conference may be submitted for inclusion in the Proceedings by sending two copies to the first editor (Rubba) so they arrive within 30 days following the Conference. (Papers and presentation summaries will not be collected at the 2001 AETS Annual Conference.) Contact information for the submitting author of the paper or presentation summary (i.e., name, address, phone and FAX numbers, and e-mail address) should appear on a page that accompanies the two copies. Each submission must be formatted as per the specifications noted below and should include: two self-addressed and STAMPED envelopes -- ONE A BUSINESS ENVELOP AND THE OTHER AN ENVELOPE LARGE ENOUGH TO HOLD ONE COPY OF THE PAPER. Papers/presentation summaries should be sent to Dr. Peter A. Rubba, 211 Mitchell Bldg., Penn State University, University Park, PA 16802.

* The 2001 AETS Conference Proceedings will not be refereed, nor will they be copyrighted. This will allow authors to submit papers and presentation summaries included in the Proceedings to journals such as the *Journal of Science Teacher Education* and *Science Education*.

* The Proceedings' editors will review papers and presentation summaries with suggested modifications noted on one of the submitted hard copies. This marked copy will be returned to the author who submitted it with a request that the paper/presentation summary be revised and resubmitted by a specified date. **One (1) camera-ready copy** and one (1) electronic copy prepared as a single (one) RTF (Rich Text Format) file will need to be submitted. The final format specifications, which will be sent with the edited copy of the paper or presentation summary, will differ from those noted below only in that page numbers are not to appear on the final paper/presentation summary.

* Review by the editors is anticipated to take about 2 months. Authors will be given about a month to revise, format and resubmit. The Proceedings will be submitted to ERIC and placed on the AETS WWW Site early in the summer of 2001. ERIC requires about 6 months to process the Proceedings. The submitting author will be notified of ERIC citation information as soon as it is available (December 2001). This information also will be disseminated on AETS-L.

* The editors reserve the right to not include in the Conference Proceedings, for example: a) documents that do not resemble what is generally considered a "paper" or "presentation summary" (overheads used in a presentation; handouts such as tables, figures and reference lists without explanatory text), b) papers or presentation summaries not prepared in final version using the specified format, c) papers or presentation summaries not submitted by a deadline and d) papers or presentation summaries not submitted as a single RTF file.

Format Specifications

APA style as presented in the 4th Edition of *Publication Manual of the American Psychological Association* should be followed except as noted below:

Font Style:	**Times New Roman;**
Font Size:	12 point, except for the paper's title, which should be 14 point;
Spacing:	Body of paper double-spaced; Paragraphs indented 1/2 inch; Quotations from interview transcripts should be single-spaced and indented on both sides;
Margins:	1 inch all sides;
Justification:	Left only;
Page numbers	Bottom center (not to appear on final paper);
Running Headings:	None;
Title/Authors:	At the top left margin of the first page of text, please list the paper's title, author(s) and institution(s) only, all single spaced;
Headings:	See example below on placement of headings; Single space within headings; Leave two blank line above first level and one blank line above all other headings;
Tables and Figures:	Place in body of the paper; (Follow APA manual recommendations on format;)
References:	Use first level heading, do not start a new page; single space within and double space between; indent first line only 1/2 inch.

- See http://www.aets.unr.edu/ for further instructions and example

<u>Mission Statement</u>
Association for the Education of Teachers in Science

We the participants in the AETS Mission Conference met in Denver, Colorado, October 31, 1993 through November 2, 1993, to develop a mission statement that will guide the Association for the Education of Teachers in Science through the 1990s.

We agreed that the mission of AETS is. . .
to promote leadership in, and support for those involved in, the professional development of teachers of science, and that AETS serves . . .

> educators involved in the professional development of teachers of science, including science teacher educators, staff developers, college-level science instructors, education policy makers, instructional material developers, science supervisors/specialists/ coordinators, lead/mentor teachers, and all others interested in promoting the development of teachers of science.

To fulfill its mission and to serve science teacher educators, the following goal statements are presented to guide AETS over the next five years. Example actions that might be taken within a one year or five year time frame are presented under each goal level.

To accomplish its mission,
AETS will be the primary voice for science teacher education

1. by identifying and suggesting actions on key issues in science teacher education.
2. by setting policy for the development of teachers of science.
3. by collecting and disseminating information about the needs of teachers of science.
4. by collecting and disseminating information on the needs of science teacher educators.
5. by setting policy for the development of science teacher educators.

AETS will provide leadership in science teacher education

1. by promoting the identification, clarification, discussion, sharing of resources, and research on issues of importance in the development of teachers of science through collaborative efforts, such as
   a) international, national and regional meetings,
   b) forums and workshops,
   c) professional development projects, and
   d) committees and task forces.

2. by producing and promoting guidelines for improving science teacher education, such as
   a) science teacher education programs and licensure,

b) elementary, middle school, high school science teaching and learning courses,
c) continuing development of science teachers,
d) alternative science teaching education and certification programs, and
e) master's and doctoral level science teacher education programs.

3. by supporting implementation of recommendations for reform as they relate to the development of teachers of science.

4. by encouraging individuals from underrepresented groups to enter science teacher education.

AETS will expand and improve the quality of its publications

1. by providing adequate guidance and support for:
    a) the Journal of Science Teacher Education by
        (1) widely disseminating clear expectations for submissions.
        (2) improving the consistency of the review process.
        (3) considering the appropriateness of theme issues.
        (4) actively pursuing library subscriptions.
        (5) creating new sections, to possibly include:
            (a) research on exemplary practices,
            (b) book reviews,
            (c) course syllabi,
            (d) implications of teacher development standards, and
            (e) articles solicited from related organizations.
    b) the Science Teacher Education section of Science Education by improving the solicitation of manuscripts.
    c) the Journal of Elementary Science Education by sponsoring a science teacher education section that is distinct from the Science Teacher Education Section of Science Education and the domain of the Journal of Science Teacher Education.
    d) handbooks and monographs on timely topics in the education of teachers of science by
        (1) aggressively recruiting highly qualified authors.
        (2) developing clear guidelines for proposals.
        (3) basing proposal acceptance on detailed prospectus and board approval.
        (4) identifying external publisher(s).
        (5) vigorous marketing.
    e) the AETS Newsletter for use as a service vehicle by
        (1) creating or expanding sections, to possibly include:
            (a) What Research Says About Science Teacher Development,
            (b) Job Opportunities,
            (c) Professional Development Opportunities
            (d) Committee and Task Force Reports,
            (e) Of, By, and For Graduate Students,
            (f) Regional News,

(g) Professional Calendar Information, and
(h) AETS Publications.
(2) actively soliciting newsletter items.
(3) increasing the number of issues to four per year.
(4) evaluating the need for a separate newsletter editor.

f) awareness pamphlets listing trends and resources in science teacher education.

g) working papers and position papers on timely topics, such as
(1) science teaching standards,
(2) science teacher education program assessment standards, and
(3) professional development standards for science teacher educators.

h) proceedings of AETS meetings.

2. by moving toward electronic delivery of AETS publications.

3. by seeking external financial support for all publications through means, such as
a) corporate sponsorships, and
b) gifts and endowments.

4. by exploring the pros and cons of advertising as a means of support.

AETS will support science teacher educators

1. by providing information resources, such as
a) the electronic delivery of
(1) an Internet GOPHER server,
(2) AETS E-Mail List, and
(3) on-line calendar of activities of education-related agencies and organizations.
b) membership mailing labels for individuals and businesses (requires approval by Executive Secretary), and
c) a speakers bureau (listing AETS members).

2. by exploring the needs of science teacher educators and by facilitating or offering professional development opportunities, that follow from those needs, such as
a) lists of instructional resources for the development of teachers of science,
b) presentations on emerging technologies and practices,
c) workshops and forums on effective approaches for the development of teachers of science,
d) national and regional conferences on the development of teachers of science,
e) workshops for science teacher educators on the use of electronic networks.
f) information and workshops on facilitating connections between schools and industry.
g) workshops and forums for improving the capabilities of science teacher educators to help teachers of science deal with issues associated with inclusion.

3. by providing membership services, such as
   b) the AETS Listserver,
   c) national conventions,
   d) regional conventions,
   e) a membership directory (for use by members),
   f) an AETS calendar, and
   g) professional discounts for members from appropriate companies.

4. by assisting regional affiliates through
   a) seed funds for conferences, and
   b) regional news in the AETS Newsletter.

AETS will initiate or strengthen liaisons with other organizations concerned with science education by establishing a standing committee

1. to exchange board seats, advisory committee and task force appointments with major organizations having compatible goals.
2. to establish joint task forces to deal with current issues and develop joint policy statements on issues in science teacher education.
3. to collaborate on joint conferences, seminars, workshops, and institutes on special issues.
4. to consider opportunities for collaborative publications.
5. to exchange membership lists.
6. to exchange early information on conferences and on invitations for proposals and participation in the conferences.
7. to exchange opportunities for exhibit space at conferences.

AETS will strengthen the organization

1. through refinement of governance structures
   a) at the national level by
      (1) changing the President-Elect's, President's and Past-President's duties to provide for a smoother transition to insure better continuity, for example
         (a) the President-Elect should oversee the annual meeting,
         (b) nominees for President-Elect should have experience on the Board, including ex officio experience, and
         (c) the President-Elect should select the Chair of the Elections Committee from the membership not currently holding office.

      (2) encouraging members at time of membership renewal to become candidates for elected office and committee membership.
      (3) considering ways to maximize the impact of AETS representation on the NSTABoard.
      (4) pursuing agreements with other associations, such as NCTM, AMTE, NARST and AAAS, to provide mutual ex-officio board representation.
      (5) considering establishment of the position of AETS Newsletter Editor.

b) at the regional level by

(1) each region establishing their own governance structure with one representative identified to the national board;

(2) the Director or the region's single representative on the national AETS Board having been a national AETS member for at least one year prior to service.

2. through strengthening the membership

a) by recruiting new members and broadening the base of the membership, including international ties.

b) by encouraging active participation of all AETS members.

c) by recruiting members from underrepresented groups.

d) by providing a one-year free membership for first year graduate students in science education.

3. through maximizing the financial viability of the association by developing a long-term financial plan that capitalizes on the following financial sources:

(a) dues,

(b) corporate/business memberships,

(c) gifts,

(d) endowments,

(e) projects/grants/contracts,

(f) grants from foundations that are other than contracts,

(g) sale of books and monographs, and

(h) income from workshops and conferences.

Mission Conference Participants:
William E. Baird, Auburn University
James D. Ellis, BSCS
Michael E. Jay, UC Berkeley & Chancery Software, Ltd.
Patricia F. Keig, California State University - Fullerton
Elizabeth S. Klein, University of Virginia
Paul J. Kuerbis, Colorado College
Norman G. Lederman, Oregon State University
Joseph Peters, University of West Florida
J. Preston Prather, University of Virginia
Peter A. Rubba, Pennsylvania State University
Deborah Tippins, University of Georgia
Javier Villalobos, Apple Computer, Inc.
Stephen S. Winter, Tufts University
Catherine G. Yeotis, Wichita State University

Index of First Authors

A Brief History of AETS

The Association for the Education of Teachers in Science (AETS) had its origins in the late 1920's with a series of visits, conferences and meetings of people involved in educating science teachers. In 1923 S. Ralph Powers was invited by Dean James E. Russell to Teachers College, Columbia University to join the faculty. Dean Russell urged Powers to visit various science teacher training institutions and confer with faculty on science teacher education standards. Visits to several campuses were followed by invitations to return the visit and come to the Columbia University campus. AETS grew out of these mutual interchanges in the late 1920's and early 1930's.

Small roundtable conferences of science teacher educators were organized by Powers and his associates. There was general agreement that these conferences were helpful and that they should be held regularly. In 1929 and 1930 a small group of heads of departments of science in institutions primarily devoted to teacher education planned a somewhat larger meeting for the autumn of 1930. Announcements were sent to the presidents of teacher education institutions throughout the East, inviting members of each science department to attend. Other invitations went to city and state supervisors in the region. A large response led to a very successful conference. The participants urged the Department of Natural Sciences at Teachers College, Columbia University, to make the conference an annual event.

A committee of four met and corresponded to plan the first formal conference of AETS that used a printed program. All science teachers from the northeast region were invited to this conference that was held in October, 1932 at Teachers College, Columbia University. Reports were given on the status of science teacher education in the represented states. Subsequent conferences were held twice annually in November and April, each lasting for two days. The 1935 meeting was titled "Conference on the Education of Science Teachers Colleges." Except for the war years of 1942-1946, this name was retained for annual meetings until 1953. Three regional sections were established in 1952 <ETH> Eastern, Midwestern, and Southern Sections.

At the business meeting in 1953, members of the "Conference on the Education of Teachers in Science" voted to change its name to the Association for the Education of Teachers in Science. In 1959 AETS became a section of NSTA and an associated organization of AOTE. A constitution and a set of by-laws were adopted in 1960. The *Guideline for the Doctorate in Science Education* was published with financial help from the Shell Foundation and the Higgins Fund of Harvard University and mailed to all AETS members in 1967. In 1968 Volume I of the *AETS Newsletter* was compiled and mailed to all members. This newsletter evolved from the practice of compiling and mailing papers presented at the annual convention. In 1969 AETS inaugurated the Outstanding Young Science Educator Award with financial support from the Shell Foundation. The first AETS Yearbook, *A Review of Research on Teacher Behaviors* by Balzer, Evans and Blosser was published in 1974. During 1978 AETS appointed its first Executive Secretary, Bill Brown for a five year term. He was followed in 1983 by Jill Wright, who was followed in 1988 by Bill Baird, Joe Peters in 1994 who was followed in 1999 by Jon Pedersen.

Reference: *AETS: An Outline of the History of the Association for the Education of Teachers in Science*. Willard J. Jacobson. March 25, 1977.

2001 AETS Conference Papers and Presentation Summaries

AN ELEMENTARY PRESERVICE TEACHER'S SEARCH FOR SOLUTIONS ABOUT THE EVOLUTION-DIVINE CREATION QUESTION: THE STORY OF TRACY.

Larry D. Yore, University of Victoria
Tracy Knopp, University of Victoria

Once again an anti-science community is trying to silence the science community or dilute its voice on controversial issues by deleting reference to the controversial concepts from the state science standards in Kansas, Alabama and Kentucky, while Oklahoma is requiring publishers to include a disclaimer in their science textbooks that identifies evolution as a controversial theory. This time the strategy is to use the democratic election process to achieve ends that the Scopes trial of the 1920s, the equal time policies of the 1960s, and the Reagan politics of the 1970s could not achieve (Good, Shymansky & Yore, 1999). The deletion strategy is a form of indirect censorship that sets the stage for local, fundamental religious, right-wing groups to pressure teachers into censoring some unifying concepts from their science programs (Benchmarks for Science Literacy, AAAS, 1993; National Science Education Standards, NRC, 1996; Pan Canadian Framework for Science, CMEC, 1997). Science educators and teachers need to realize that the attacks are not always from the "right" and they need to be alert to the dilution of canonical science by the "all opinions are equally valid" approach of the radical postmodern left-wing of academia (Good, Shymansky & Yore, 1999; Gross & Levitt, 1994; Gross, Levitt & Lewis, 1996). The approaches by fundamental Christians, racial postmodernists, feminists and multiculturalists are no less dangerous than book burning, court cases or thought police and they will put the most vulnerable teachers at risk (Singham, 1999). What can science educators and teachers do about these censorship attacks?

This paper will attempt to provide background about the anti-science censors in a context of elementary school science and to provide strategies that science educators and elementary

school teachers can use to address and to prevent such attempts. What are the issues, who are the combatants, and how do generalist teachers address the controversy when teaching elementary school science? These were the central questions that guided Tracy's quest for solutions. Anti-science controversies are not reserved for the deep South, or the end of the yellow brick road in Kansas in the USA; the liberal North in the USA and Canada also face these controversies. Tracy's search for problem identity, search for solutions and resulting solutions provide guidelines for ideas and activities that could be included in preservice courses and professional development activities for generalist elementary teachers.

Background

The 2000 federal elections in Canada and the United States of America highlighted the potential impact of religious fundamentalists on government and policies. Both George W. Bush, the President Elect of the USA, and Stockwell Day, the Leader of the Loyal Opposition in Canada, have declared their belief in an evangelical religion. Their personal beliefs are based on a literal interpretation of the Bible as God's exact words, laws and directions. Mr. Day publicly affirmed his belief in a Genesis-based creation, a young earth (6,000 years old) and that dinosaurs co-existed with people. Many (38%) Canadians participating in a recent survey expressed beliefs that supported a biblically based Divine Creation (Owens, 2000), although only 39% of the respondents expressed any concern that the political leaders' personal beliefs would influence their ability to fairly lead the country. These data are also likely reasonable representations of the public opinion in the USA, since 38% of American university students surveyed believed life originated in the Garden of Eden (Hively, 1988). Sinclair and Pendarvis (1997/1998) found that many university students taking introductory biology believed they must

reject evolution or face violating their religious beliefs. They also found a sizeable number of students did not improve their basic understanding of evolutionary biology during the course. Could the students' internal conflict between their personal beliefs and modern biology hinder their science literacy?

With this type of public understanding of evolution and creationism, it is not surprising that public education and schools are facing controversy over the inclusion of evolution, cosmology and ecology in the science curriculum. In fact, it is surprising that there is not more wide-spread conflict about these issues. Part of the reason for the lower than expected conflict is that some scientists and religious people have worldviews that do not conflict. Elite science, popular science, elite religion and popular religion position themselves on the controversy differently and promote different resolutions to the conflict-- religion trumps science, science trumps religion, independence, and integration (Nord, 1999; Singham, 2000). Those scientists and religious people belonging to the independence camp have found a compromise solution involving two worlds based on their interpretations of science and religion and that these domains involve different epistemologies. Science is a knowledge system based on evidence, claims, and warrants designed to address how patterns of events in the natural universe occur; while religion is a belief system based on faith in specific collections of narratives designed to address why singular events, like miracles, occur. Therefore, these people have compartmentalized their ways of knowing into two distinct and mutually exclusive epistemologies that are not allowed to conflict.

The National Academy of Sciences (1998), the National Association of Biology Teachers (1995), and the National Science Teachers Association (1997) advocate that both science and religion are useful, separate and mutually exclusive ways of knowing about different things and

neither should be used to disconfirm the assertions, beliefs or claims of the other epistemology. About 40% of scientists report holding a religious belief "in a personal God as defined by the statement 'a God in intellectual and affirmative communication with man...to whom one may pray in expectation of receiving an answer" (Larson & Witham, 1997, p. 435). Scientists and people ascribing to a two worlds view are "respectful of science and its accomplishments but also believe in a deity and are active members of churches, temples and mosques. Such people view the creation narratives in their religious texts as figurative and metaphorical—not as records of actual historical events" (Singham, 2000, p. 427).

"The major Western religions--Judaism, Christianity, and Islam--have made sense of reality not in terms of universal causal laws but in terms of narratives. Events become intelligible not because they are lawlike but because they fit into a narrative (as miracles might). Theologians discern patterns of meaning and purpose in history and nature that they understand in terms of a divine causality in the world" (Nord, 1999, p. 29). It is precisely how literal and rigid these interpretations of scripture and to what degree divine causality are ascribed that defines the interface of the science-religion conflicts. Pope John Paul II (1996) affirmed that the theory of evolution had strong scientific support and did not contradict the teaching of the Catholic church as long as it did not impose a scientific causality for people's souls. This integration approach to religion and science attempts to achieve a unified interpretation of scientific inquiries and religious narratives, such as evolution as a divine approach to creation initiated by God and guided by God. This approach encounters resistance from scientists in the degree and frequency of God's intervention in the evolutionary process. Some scientists will accept the initial intervention by God, but reject any further intervention by God. Nord (1999) stated "neither [science nor religion] can ignore the other, and neither automatically trumps the

other. Because science and religion are each competent to illuminate aspects of the same reality, a fully adequate picture or reality must draw on--and integrate--both" (p. 30).

The two winner "takes all" approaches (religion trumps science, science trumps religion) to the current controversy involve the central combatants in the evolution and divine creation conflict. One group believes that it "is through inerrant scripture or religious tradition that we come to know the ultimate truth about nature. ...[while the other group believes it] is through the methods of science that we learn the ultimate truth about nature" (Nord, 1999, p. 29). It is the misconceptions about the nature of science and the nature of religion that appear to be at the center of these conflicting groups. Some scientific and religious people incorrectly believe that science deals with absolute truth and focus on the question of why, they do not accept the purposes of religion as dealing with why people exist and their ethical and moral behavior, and they believe that religious documents are historical or scientific text rather than a collection of narratives used to establish philosophical assertions dealing with the meaning of life and living. The lack of awareness and intolerance of scientific people for the values of religion as a way of knowing the deeper meaning of life and living frequently cause red flags to be flashed unknowingly to religious people. Likewise, the anti-science stance based on an absolutely literal interpretation of religious narratives and the rigid moral discontinuity between science and religious laws and canons causes scientific people to respond in an attack mode to defend their territory.

There is a lack of common language used by both sides of the conflict. Frequently religious people will refer to "Evolution as just a theory" emphasizing its tentative and potentially temporary nature. Meanwhile the scientific people respond in a gleeful manner, acclaiming yes, evolution is a theory, emphasizing its umbrella, unifying and explanatory nature.

Clearly, the debaters are not addressing the evolution-creation issue, with a common understanding of their and the opposition's epistemologies.

Shingham (1999) describes one strategy in which "creationists try to drive a wedge between elite science and elite religion [attempting to use an independence or integration resolution to science-religion conflicts] by arguing that, at a fundamental level, the scientific and religious world views are incompatible and that both cannot be believed simultaneously" (p. 429). This strategy tries to emphasize that if science is given domain over the physical world it will quickly assume dominance over the spiritual world as well. The fundamental religious right appear to believe that their interpretation will fall like an house of cards if the absolute word of God is not defended on all fronts. Part of the attack strategy involves the development of Creation Research Society (CRS) to promote scientific creationism and alternative Bible-based theories to Darwin's theory (Numbers, 1993). CRS scientists argue that the evidence is weak for evolution, that it is an illogically conceived theory, that it lacks predictive validity, and that evolution is sparsely supported within the scientific community (Johnson, 1991). This dilution of good science with pseduoscience endangers the credibility of the entire scientific enterprise. Numerous scientists, including Stephen Jay Gould (1992) and Francisco Ayala (2000), have countered these claims. The National Academy of Sciences (1998, 1999) has provided two excellent resources that provide an overview of the theory of evolution, its scientific support, and the associated conflicts with religion, which are readable by most adults with a limited science background.

The science-religion conflicts are reinforced by the fringe ideas and dilution strategy of the popular science communities and their beliefs about superstitions, astrology, magic, witchcraft, psychokinesis, extrasensory perception and attacks on the nature of western science

and the organization of the scientific community (Good, Shymansky & Yore, 1999; Singham, 1999). This consortium of historians, philosophers, and radical constructivists have concluded that "there is no compelling reason to believe that scientific progress is leading to the truth about the physical world or even that there is such a thing as the truth of objective reality. ... Thus science cannot claim that its knowledge structure is objective and unique, and this has led to the discussion of possible alternatives, such as feminist science and multicultural science, in contrast to the present 'orthodox' science" (Singham, 2000, p. 431). The religious combatants have grasped on to some of the fringe science ideas as their focus of attack in an attempt to illustrate to the larger audience how untrustworthy and irrational science is. Furthermore, the radical postmodern community appear to be willing to form alliances with other groups attacking elite science regardless of their allies' motives and strategies. "The scientific community has been somewhat flummoxed by the wide-ranging nature of the criticisms it has received" (Singham, 2000, p. 431) and the unwitting postmodern science reformers have apparently become dupes of the fundamental right-wing Christians, who in turn reject much of the common glue unifying the radical postmodernists.

In summary, it is critical that elementary school teachers be aware of the controversial issues in science, who might take offense at these issues, what strategies might these combatants use, who might be allies to the offended parties, what a teacher should do to avoid conflict and prepare for unavoidable conflict, and what resources are available to elementary teachers involved in such conflict. Clearly, being knowledgeable about the science and the scientific-religious issues is of prime importance in making informed instructional decisions. Secondly, elementary teachers must be willing and able to defend their instructional decisions using current research and professional literature. Thirdly, elementary teachers must be confident that

teaching to the national, state-wide, provincial or district-wide science curriculum framework is their legal mandate.

Context of the Case Study

This 4-year case study focussed on how Tracy, the co-author, a Year 5 undergraduate student concentrating in elementary school science education at the beginning of the study, and now an experienced international elementary teacher, addressed the challenges anticipated in teaching controversial issues, like evolution, in elementary school science. Actually, this case study documents the reflective journeys of both authors, as they have been involved in an action research activity in which Tracy's concerns have served as the foci for much inquiry and reflection by both parties-- Tracy trying to become a more effective elementary teacher and Larry trying to become a more effective science teacher educator.

British Columbia has had a history of conflict involving a school district located in a region heavily populated with fundamental Christians and having a conservative school board. The school board mandated equal time for the Divine Creation when the Theory of Evolution was presented in Biology 11 (Good, Shymansky & Yore, 1999; Gopaul, 1995). The local teachers union and the school board were unable to resolve the conflict, and the Minister of Education decreed that Divine Creation was not a scientific theory and such pseudoscience should not be included in science courses authorized by the British Columbia Ministry of Education. The Minister of Education's proclamation ended this conflict on the surface, but similar science-religion conflicts still exist just below the surface with candidates for recent School Trustee elections being surveyed about their positions on "Are you in favor of encouraging students to think critically about whether scientific evidence supports evolution or

creation?" and other traditional values-oriented issues by the local chapter of the Canada Family Action Coalition (Novemeber 20, 1999). Local Christian media continuing to provide information about the Creation Science Association of British Columbia (Island Chistian Info, 18(1), January 2001) and states:

> In recent years, scientific evidence has been piling up against the theory of evolution and in favour of biblical creation. However, our news media and educational system will not abandon evolution without a battle. The theory has held sway for almost 150 years and, because it provides a way for some people to eliminate God from their thinking, every possible means will be used to bolster up this unscientific model.
>
> In evolution there is no fall from perfection, no sin and no necessity for a Saviour. Evolution strikes at the very heart of our Christian faith. There are many scientific evidences that do not support evolution, yet it is taught as a fact to our children even in the early elementary grades in public school. (p. 9).

This clearly illustrates the confrontational or at least chilly climate that beginning elementary teachers entering a career in British Columbia public schools face --curriculum documents that mandate the teaching of evolution and a hostile public with a vocal component that does not want it to be taught.

Tracy enrolled in a self-directed study course with the other co-author to investigate this evolution-creationism controversy, to identify the controversial science and religious issues and the combatants, and to design potential avoidance and resolution strategies. Tracy spent the spring term of her graduating year reading, interviewing, and reflecting. Tracy prepared a summary paper of her inquiries and findings. Three years later, after Tracy has been teaching in

public and private elementary schools in Canada and England, this paper summarizes the interactions between and reflections of the authors about her quest and current beliefs.

Results and Reflections

The major sources of information for this paper have been a course paper and discussions between a preservice elementary school teacher and a science education professor, the intervening readings, emails, and telephone conversations between the authors. An analysis of the original paper and further inquiries and conversations resulted in confirming and elaborating several of Tracy's themes. These themes have served as the organizational framework for the paper.

Historical Origins

Tracy discovered the history of the controversy had origins from the time of the publication of the Origin of Species in 1859. Thomas Henry Huxley and Herbert Spencer used the theory of evolution to justify their social activism and to confront the Church of England's authority (Ruse, 2000). These early conflicts were reactivated in the 1920s with the Scopes trial (1925) and 37 states' attempts to ban or limit the teaching of evolution in science courses (1921-1929). Three states—Arkansas, Mississippi, and Texas—actually passed such laws.

Contemporary philosophers believe that the early attempts to use evolution as a tool to overcome the power of the church and to raise evolution to a religion may be in part a cause of the current hostility of the fundamentalist churches against the teaching of evolution in public schools (Ruse, 2000). These early conflicts appear to have attached a red flag to Darwin's work and to any associated research coupled to the inferential work using fossil records. These

defensive stances have turned a blind eye to much of the recent genetic and biochemical evidence about evolution.

Combatants

Tracy was somewhat surprised to find that not all Western religions were in open conflict with the teaching of evolution. Her discussion with a minister revealed religions that did not ascribe to a strict literal interpretation of their religious texts were able to either integrate evolution ideas into their belief system or co-exist into two parallel worldviews thereby avoiding conflict. These liberal religions including Catholics, Lutherans and other mainline protestant religions are able to separate their faith-based religious beliefs from their evidence-based scientific knowledge. But, Evangelical churches like Pentecostals, Reformed Christian and other fundamentalist religions base their beliefs on a literal interpretation of the scriptures as God's exact word. Any disproof of a single scripture's literal message would put at risk the entire set of scriptures and their literal messages and the foundational assumptions of these Evangelical Christian religions. There can be no compromise for fundamentalist religions.

Science Reform Documents

Tracy found that both the American and Canadian science reform documents promoted evolution, change and diversity as big ideas or unifying concepts in science (AAAS, 1993; CMEC, 1997; NRC, 1996). Clearly the authors of the current reform documents believe that these ideas are a critical foundation to understanding modern biology and science literacy. The National Science Education Standards (NRC, 1996) specifically lists evolution and equilibrium as a unifying concept, but it should not be taken out-of-context of the other unifying concepts (evidence, models and explanation) and content standards (science in personal and social perspectives, history and nature of science). The authors expressed a sensitive to other

epistemologies by stating "Explanations on how the natural world changed based on myths, person beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific" (NRC, 1996, p. 201). Clearly, the reform documents were trying to control the level of conflict and to encourage teachers to avoid any hint of winner-takes-all confrontation.

Conflict Strategies

Tracy was able to detect that anti-science groups used a variety of strategies to attack evolution. They have tried legal strategies. Most legal attempts to delete evolution from public school science curricula or to include equal-time for creationism have been unsuccessful (Bybee, 2000). They have used the democratic election process to take control of school boards and to pass school policy to achieve their goals. Clearly, with a minority of the electorate taking the option on their voting rights in major elections and even smaller percentage actually voting in local community and school board elections, there is a real danger of this strategy working for the anti-science lobby. A similar approach has been used with hospital boards and foundations in which conservative anti-abortion groups gained control and have required these facilities to stop providing comprehensive health care to women. This can and does happen to school boards (Good, Shymansky & Yore, 1999). Anti-science activists have used dilution strategies by developing pseudoscience groups, like the Creation Research Society. This strategy has had the least success in that it quickly confronts the established scientific community which is well organized and practiced in addressing sociopolitical attacks on science and research funding.

Language

Tracy found that parties in the conflict were not using a common language. An article (Miller, 1997) and a letter to the editor (Currie, 1997) in the Canadian Lutheran, a magazine

published by the Lutheran Church-Canada, revealed the discrepant worldviews and use of the term 'theory' by people with varying degree of science literacy. Miller (1997) writes:

> Evolutionists and creationists observe the same evidence. There is not one set of fossils that is creationist fossils and another set that is evolutionist. The difference is in the interpretation. It is a conflict between two differing world views; a war between two opposing faiths. Evolution is a faith. Even some evolutionists recognize this as seen in this quote: 'The fact of evolution is the backbone of biology, and biology is thus in the peculiar position of being science founded on an unproven theory-- is it then a science or a faith?' (p. 7)

He continues to examine the evidence, science and scriptures about the origin of life, the change of simple organisms to complex creatures, the age of the earth, people's relationship to apes and concludes that Divine Creation is an equally plausible explanation as evolution.

Two issues later, Currie (1997) writes:

> I am angry and disgusted that an official publication of my church would publish an anti-science diatribe like [Miller's] *Evidence for Origins* (April, 1997). The theories and allegations expressed in this article have been repeatedly and comprehensively discredited. Readers wishing a better informed and more balanced Lutheran approach to the questions raised in this article should consult *Rock Strata and the Bible Record* edited by Paul Zimmerman (Concordia Publishing House, 1970), a collection of studies by professors from Missouri Synod seminaries and scientific experts which outlines theological and scientific positions and finds little conflict between them.

Clearly, many religious people view both science and religion as absolute bodies of true and proven knowledge with a common epistemic foundation and lexicon. Science literate people

view science as an evalutivist domain based on evidence that is people's attempt to search out, to describe and to explain patterns of events in the natural world which does not necessarily involve absolute truth. The scientific enterprise seeks to formulate unifying, umbrella concepts, called theories, that will improve the descriptive, predictive and explanatory power of science, but recognize that these ideas are still tentative and temporary. Religious people with a less well developed science literacy incorrectly impose their absolutist epistemology and lexicon on science. They focus their discourse on the tentative and temporary features of the Theory of Evolution, which the scientific community openly acknowledges, when debating the values of Divine Creation and Evolution. They discount the unifying, umbrella and power aspects of theories and concentrate on build an argument that emphasizes the limits of the evidence base and skepticism about the Theory of Evolution within the scientific community. They forget to mention that the same skepticism in the scientific community applies to all science ideas and is a critical scientific habit of mind. Furthermore, they fail to mention that the supportive evidence for the Theory of Evolution is becoming overwhelming and that the skepticism is about the hyper-fine procedural details of evolution, not about the general conception of evolution (National Academy of Sciences, 1998).

Nature of Science and Nature of Religion

Tracy found that the epistemologies of science and religion were not well understood and that people's and teachers' misconceptions about the nature of science and nature of religion lead to conflict. Many teachers' misunderstandings about science's purposes lead them to dogmatically present science ideas as absolute truths rather than as inquiry leading to temporary descriptions and explanations of patterns of events in nature. Likewise, she found that their misconceptions about religion did not identify its purposes as how to live a meaningful life and

the central issue of why people exist. Religion identifies where people came from, where they are going, and what they should do along the way (Ruse, 2000). Few people realize that "science and religion are on opposite [not opposing] sides of human experience" (Krauss, 1999, p. A86).

Bybee (2000) encourages teachers to avoid debating supporters of Divine Creation and to concentrate on educating them about the nature of science. He states "debating groups that advocate creationism positions for the school curriculum place science teachers in positions for which they are not prepared and are outside the realm of tasks the public school expects of them. On the one hand, debating requires a huge expenditure of time and energy and results in little or no change among those advocating nonscientific positions. Also, in such debates there is every possibility of leaving creationists with more power and the public with greater confusion about science and science education" (p. 34). Bybee suggests embedding nature of science ideas in any instruction about controversial issues, like evolution, the Big Bang theory, and the age of the earth. He cautions teachers about insuring that science is presented as problem-driven inquiry and not as an absolute body of truths and an unerring systematic, lock-step method of unconnected processes and mindless procedures.

Tracy found that utilizing common misconceptions about science (McComas, 1996) and the science reform documents (AAAS, 1993; CMEC, 1997; NRC, 1996) as a framework for self-directed study and instructional planning a useful starting point. It was apparent that parallel resources about religion were not readily available to elementary teachers and that she needed to rely on her own religious background and on personal inquiries into religions and their concerns about science. Nord (1999) believes that public schools and universities should provide comparative, parallel instruction about science and religions such that future students will be equipped with the habits of mind, critical thinking, and conceptual background to address

controversial issues with the dual literacies of science and religion. Clearly, people must realize that "science deals with ideas that are falsifiable, [while] religion deals with matters of faith. It is of vital importance for both fields that they stick to their separate turfs. ... [The] ultimate arbiters of the origin and evolution of life will be biology and perhaps astrophysics, not theology. By the same token, the moment that scientists attempt to prove or disprove the existence of God, or divine purpose, they have stopped being scientists" (Krauss, 1999, p. A86).

Strategies

Tracy's experiences have illustrated the need to provide preservice teachers and elementary teachers with specific background about controversial science issues and the groups that are involved in the controversies and guidelines for teaching controversial issues (Good, Shymansky & Yore, 1999). The three strategies that follow flow from Tracy's four-year quest.

Knowledge about Controvesial Science Issues

Preservice teachers and elementary teachers need to be provided a concise, but comprehensive overview of controversial science issues dealing with cosmology, evolution, and ecology. Generalist teachers are unlikely to take and understand upper-level evolutionary biology courses and it is questionable if a single entry level biology course will provide sufficient content background (Sinclair & Pendarvis, 1997/1998). Many people, including preservice teachers, tend to generalize that all science ideas are contested by all religions, rather than realizing that specific issues dealing with the formation of the Universe, the age of the earth, evolutionary changes of simple organisms into more complex organisms, and the genetic and evolutionary relationships between primates and people are contested by Evangelical Christian religions that use a literal interpretation of Genesis as the foundation for creation (Nord, 1999;

Singham, 2000). The National Academy of Sciences' (1998, 1999) publications and the national science reform documents (AAAS, 1993; CMEC, 1997; NRC, 1996) are comprehensive, readable sources for a basic understanding of the controversial science topics. These documents should be readings for any preservice or inservice activity dealing with the teaching of science.

Knowledge about Religious Groups

Concise, understandable resource materials about religions and their support of or concerns about science are difficult to find. Most materials do not consider a broad spectrum of Eastern and Western religions needed to cover the current multicultural classrooms in Canada and the United States. Singham (2000) discusses the concerns that popular religions have about cosmology, ecology and evolution, but he does not provide a specific listing of these religions. He does identify some elite Western religions (Catholic, mainline protestant) and Eastern religions that do not contest these science issues, but again does not list the specific religions. Teachers need an unbiased overview of religions and their fundamental assumptions and practices to develop an awareness about and sensitivity for personal belief systems in their classroom. Religious scientists who have adopted an independence or integration solution to the science-religion conflict should develop such a resource for teachers that identifies the epistemic and propositional foundations of religions.

Guidelines for Addressing Controversial Science Issues

Teachers in Canada and the United States need to utilize the position statement provided by the National Science Teachers Association (1997) for teaching evolution as a basic foundation for instruction. This brief two-page document provides a concise science position that can easily be adapted by a sensitive teacher who is aware of students' philosophical beliefs and their misconceptions about controversial science ideas. A sizeable number of scientists

express an integrated or independent view of science and religion in which they accept a god, who in the beginning initiated the events into motion. Such views accept the different epistemic formation of science and religion and the different foci of these domains--how and why.

Bybee (2000) provides good advice to teachers to avoid debating and focus on educating advocates and adversaries about the nature of science and the importance of the theories of science as umbrella ideas that unify and explain the nature of the physical world and how it works. McComas ' (1996) 10 myths about science is a good starting point for most elementary teachers who are planning instruction about the nature of science. Teachers need to emphasize that science focuses on how things occur and not on why things occur and that science is based on inquiry, evidence and justification leading to tentative knowledge claims about how the physical universe works.

Teachers should accept their professional and legal responsibilities to teach about the creation of the universe, evolution, and ecology, but they should not irrationally infuse these ideas into their science instruction as red flags (Gopaul, 1995). The thoughtless inclusion of controversial science issues bring on unnecessary conflict. Introducing the creation of the universe, the age of the earth, the natural selection of surviving species, and people's genetic and biochemical relationships to other organisms should be done as part of a well-planned, unified and conceptually integrated unit of study.

Discussion

This paper reflects the authors' evaluativist view of science and liberal protestant religious background. The language and metaphors of conflict were selected to illustrate the confrontational attitudes of the extremists from both the scientific and religious communities and

to focus the readers' attention on the importance of this science-religion war. We believe that you can not be a passive spectator during this conflict and others that will likely follow.

This case study illustrates three critical considerations for preparing elementary teachers to address teaching evolution and other equally important controversial science topics. Teachers need to know the content knowledge associated with the topic, they need to present these controversial topics and all science ideas in the context of the nature of science, they need to have an awareness and appreciation of alternative non-science interpretations of these topics, they need to cognizant of community sensitivities and signs of conflict, and they must not introduce "red flag" topics unless they are essential to their development of science literacy. Teacher educators and teachers need to prepare themselves to address controversy in general, not just the evolution-creation controversy. Numerous lobby groups are ready and willing to attack Western science using frontal conflict, democratic processes, legal battles, and dilution techniques (Good, Shymansky & Yore, 1999).

It is critical that teachers understand that science and religion are of two worlds and two different, not necessarily conflicting, ways of knowing about the physical and spiritual worlds. Science must test its ideas against the evidence of Nature using the traditions, accepted procedures of inquiry, and the canons of evidence of the scientific community. Religion is a philosophy, not a science, based on faith and the message contained in a set of narratives. These interpretations are to be accepted, not to be tested. Luke 4:13 states "Jesus answered, 'It says: Do not put the Lord your God to the test' ." Likewise, it seem foolhardy to put science to a religion-based evaluation. Let the two worlds co-exist.

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STARS: EVALUATING THE USE OF VIDEO TECHNOLOGY FOR MODELLING SCIENCE PROCESS SKILLS

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This project explored the feasibility of developing a mechanism by which elementary children were given the opportunity to observe positive role models of appropriate children's behavior in a science classroom. A series of videotapes and instructional manuals were developed to support the needs of teachers and students to develop skills among students consistent with those required to participate in an inquiry-based science program. Staff development programming was developed to assist teachers in the implementation of the materials, and a subsequent series of classroom observations examined the value of the materials in terms of the nature of teacher-student classroom interactions.

The authors of this paper have both recently returned from observing student teachers. It was evident that both preservice and practicing teachers were disinclined to teach science in a manner consistent with the hands-on/minds-on approach advocated by the American Association for the Advancement of Science (AAAS, 1989), the National Research Council (NRC, 1996) and the State of Illinois Learning Goals (Illinois State Board of Education, 1997). Their objections typically related the difficulty in establishing classroom behaviors that will enable children to participate effectively in a classroom where individual autonomy, freedom and manipulation of materials are the norm (King, Shumow, & Leitz, 2000; 2001). Lynes and Oshita (1998) report similar

findings from their work with science teachers, that the need for student autonomy, classroom management issues, and a inquiry-based approach to learning science.

When teachers are asked to comment on why they are reluctant to have children manipulate materials in a hands-on science program, their responses typically included: discipline gets out of hand, children can't handle the freedom, it takes too much time, children can't work with other children, or it is too noisy (King, Shumow, & Leitz, 2000; 2001). To address these obstacles to hands-on/minds-on science instruction, providing a set of model behaviors for students to emulate would do much to address the needs of both teachers and students.

Classroom teachers who were reluctant to have their students participate in a hands-on science program will show those images to their elementary students. By showing video images of young children engaging in appropriate behavior that is associated with inquiry science investigations, other children will then find a peer role model to model their own behaviors. This project videotaped images of culturally diverse children engaged in different aspects of inquiry science. Documentation to support the use of these videos in the classroom was developed for use with the videotaped materials (King & Thompson, 1999a; 1999b; Thompson & King, 1999).

<u>Research Questions</u>

To organize provide focus for this study, the following research questions were developed:

(1) *Is there an increase in higher-level classroom discourse that correlates with the use of the instructional materials?* This is important, as the value of the material is to

focus classroom interactions on the behaviors consistent with inquiry-based classroom instruction.

(2) *Do the level of classroom management interactions remain constant during the school year as a result of the use of the instructional materials?* Findings cited elsewhere in this paper show that an increase (often dramatic) in classroom management interactions is related to students participating in an inquiry-based set of classroom experiences (King, Shumow, & Lietz, 2000). Keeping classroom interactions at the same level as during expository teaching (or finding a decrease) is desirable for teachers and students engaging in hands-on/minds-on science.

(3) *Is there an optimum combination of instructional materials that supports improvement in classroom interactions?* This question examines the materials students were exposed to during the treatment portion of the investigation. Students were given the opportunity to view video episodes of students using inquiry skills, perform activities using inquiry skills, or a combination of the two experiences.

Experimental Design

The design selected for this investigation is outlined in Table 1 below. Four conditions were selected for examining the value of the instructional materials. Eight classrooms participated in the study. Two classrooms were randomly assigned to each of the conditions. This design allows for effective control of internal and external validity issues (Campbell & Stanley, 1963).

Table 1.

Experimental conditions for project evaluation

Initial Observation	Video	Activities	Subsequent Observations
1. RO_1			O_2 $O_{2'}$
2. RO_3	X		O_4 $O_{4'}$
3. RO_5		X	O_6 $O_{6'}$
4. RO_7	X	X	O_8 $O_{8'}$

Condition 1 provided the control group. Two teachers participated in the September 1999 workshop, but did not use any of the instructional materials during the school year. An initial observation (O_1) took place during October 1999, shortly before the workshop. Subsequent observations (O_2 and $O_{2'}$) took place during November and January. Condition 2 represented exposing students to the video materials only, with an initial and then three post-treatment observations. Condition 3 represents exposing students only to the activities in the instructional manual that develop through hands on interaction with activities that focus on the process skill. Condition 4 captures students using both the video materials and the associated hands-on activities.

Theoretical Implications and Relations to Previous Work

This study examines issues in two areas: the use of video as a modeling tool and the examination of teaching behaviors through a methodology examining levels of instructional discourse developed by Shumow (1998). The modeling feature of the project was employed through the use of the videotaped process skill episodes and the classroom observations recorded changes in behavior resulting from the video experiences.

Modeling

The value of modeling as a teaching and learning tool is evident, as demonstrated in the work of Bandura (1986). For these models to work most effectively, they must be perceived by the viewer as being believable. The models must also demonstrate behaviors that can be incorporated by the viewer. By using elementary students as models, it is anticipated that the behaviors demonstrated by the student models captured on video will provide a model for behaviors desired of elementary students participating in inquiry-based science investigations. The act of modeling is critical in science education as well. Brna and Burton (1997) further made a case for modeling as an essential part of the science education experience. White and Fredricksen (1998) have advocated developing curricula that supports this process in science teaching. The materials developed for this study not only provide behavioral models for students, but the students in the video also help to model the role of modeling in inquiry-based science activities.

Classroom Discourse

Examining classroom behaviors through an objective means provided the method of examining classroom practices for changes promoted by the use of the video materials. The coding scheme employed was previously modified from prior observational studies of adult teaching of elementary school students within the framework of NCTM mathematics reforms (Lehrer & Shumow, 1997; Shumow, 1998). This scheme focused on a number of the instructional strategies suggested by the science reform documents and entails coding each statement that the teacher made during the lesson on two

dimensions. The first dimension, "involving", characterized (yes/no) whether the teacher's statement prompted the students to engage in (higher order) thinking.

The second dimension, called "purpose," categorized the function the teacher's statement served in the lesson. These purposes include focusing on either a) knowledge, givens, or problem definitions, b) moving the flow of the lesson forward, c) elaborating including hypothesizing, comparing and contrasting, explaining, or justifying, d) modeling including demonstrating, creating representations, or analogizing, e) managing student behavior, and f) attending to interruptions.

It is an assumption by the authors of this study that the behaviors captured (levels of discourse) were impacted by the exposure to the instructional materials. Given that the skills associated with inquiry-based science instruction are consistent with those behaviors described in the coding scheme, it is reasonable to infer that changes in teacher-student interactions will be captured by the methodology.

Background on the Participants and Schools

The participants in the study were selected from among the teachers and students in School District U-46, in Elgin, IL. School District U-46 is the second largest school district in the state of Illinois. It is a vast and varied district, with a large number of students from underrepresented populations and a wide range of socioeconomic levels. In 1998, U-46 served over 34,000 students. The district reported that some 66 different languages were spoken among U-46 students in a recent school district census. Approximately 26% of U-46 students are of Hispanic origin, 8% are African-American, 6% are Asian-American, and less than 1% are Native American (School District U-46,

1999). The students participating in the investigation reflect the overall demographics of the school district.

Procedure

The procedure employed in this study was carried out in two phases: staff development and classroom implementation. The staff development process trained all of the participating teachers in the use of the materials. An instructional manual accompanied each video, with suggestions as to how to use the videotapes as a discussion and modeling guide. Contained in the manual were a set of activities to profile the essential issues of the process skills covered in each tape. Teachers viewed the tapes with the guidance of the project developers and discussed how to use them to foster knowledge of the process skills. Teachers also experienced the science activities suggested in each instructional manual as a means of further developing their own understanding of science inquiry skills. At the conclusion of the workshop, the teachers were randomly assigned to one of four experimental conditions.

Prior to the workshop, each of the teachers was videotaped teaching a science lesson. This lesson was used to provide a baseline for each of the classes observed. After the workshop, the teachers and their classes were videotaped three subsequent times, to look for changes over time. The videotapes were analyzed and the teacher-student interactions classified according to the observation scheme described previously.

Results

The results are summarized in Tables 2 - 9 below.

Table 2.

The instructional functions served by each teacher's classroom discourse. (Control groups*)

	Teacher 1		
	Pre-treatment Observation	Post-treatment Observation (1)	Post-treatment Observation (2)
Information Focus	26.4	28.9	15.6
Sequential Flow	41.1	51.6	59.7
Elaboration	11.7	2.4	9.4
Modeling	0	5.1	3.9
Classroom Management	20.8	12.0	11.4

*Note. The lessons were approximately 40 minutes in length.

The second set of control group observations is summarized in Table 3. Teachers in this group showed increased in sequential flow interactions and modeling interactions. Information focus, elaboration, and classroom management instructional interactions all decreased during the time of the study.

Table 3.

The instructional functions served by each teacher's classroom discourse. (Control groups*)

	Teacher 2		
	Pre-treatment Observation	Post-treatment Observation (1)	Post-treatment Observation (2)
Information Focus	26.0	24.1	15.1
Sequential Flow	47.6	51.6	72.0
Elaboration	17.9	11.0	8.2
Modeling	0	6.2	2.2

Classroom Management	8.5	7.2	2.5

*Note. The lessons were approximately 40 minutes in length.

The second classroom serving as a control for the investigation demonstrated increases in sequential flow and modeling measures. Information focus, elaboration, and classroom management interactions all showed decreases during the period of the investigation.

Teacher 3, who made use of both the videotapes and the process skill activities demonstrated interactions with students showed increases in elaboration, modeling, and classroom management interactions. Over the period of the investigation, sequential flow remained essentially unchanged (moving from 64.0 to 63.5 percent of observed interactions over the period of the study). Decreases were observed in the construct of information focus.

Table 4.

The instructional functions served by each teacher's classroom discourse. (Both treatments*)

	Teacher 3		
	Pre-treatment Observation	Post-treatment Observation (1)	Post-treatment Observation (2)
Information Focus	32.5	23.1	20.6
Sequential Flow	64.0	69.8	63.5
Elaboration	0.6	3.9	5.8
Modeling	0	2.0	1.1
Classroom Management	2.9	1.2	9.0

*Note. The lessons were approximately 40 minutes in length.

Table 5.

The instructional functions served by each teacher's classroom discourse. (Both treatments*)

	Teacher 4		
	Pre-treatment Observation	Post-treatment Observation (1)	Post-treatment Observation (2)
Information Focus	23.0	19.5	10.3
Sequential Flow	54.6	64.3	70.0
Elaboration	9.5	7.5	11.5
Modeling	5.0	0.9	1.0
Classroom Management	6.7	7.9	7.3

*Note. The lessons were approximately 40 minutes in length.

Teacher 4 also made use of both the video materials and the activities. Observations show an increase in terms of the sequential flow, elaboration, and classroom management constructs. Information focus and modeling both decreased.

Table 6.

The instructional functions served by each teacher's classroom discourse. (Activities alone*)

	Teacher 5		
	Pre-treatment Observation	Post-treatment Observation (1)	Post-treatment Observation (2)
Information Focus	30.7	32.8	37.0
Sequential Flow	45.7	42.9	44.5

Elaboration	10.6	18.4	11.1
Modeling	1.4	0.7	1.7
Classroom Management	12.2	5.1	5.6

*Note. The lessons were approximately 40 minutes in length.

Teachers 5 and 6 used only the process skill activities to provide instructional models for their students. In the case of Teacher 5, a 6.3 percent increase in modeling utterances was observed, as well as smaller (0.5 and 0.3, respectively) increases in elaboration and modeling. Sequential flow decreased slightly, and classroom management utterances decreased by over 6 per cent.

Teacher 6 taught in a bilingual classroom. English was not used in classroom instruction in science. For these observations, information focus remained constant over the time of observations (including one dramatic drop before returning to pre-treatment observation levels). Sequential flow and modeling both decreased. Elaboration and classroom management interactions both increased.

Table 7.
The instructional functions served by each teacher's classroom discourse. (Activities alone*)

	Teacher 6 (Bilingual)		
	Pre-treatment Observation	Post-treatment Observation (1)	Post-treatment Observation (2)
Information Focus	22	7.3	22
Sequential Flow	53.8	59.2	47
Elaboration	5.5	15.5	15
Modeling	14.3	6.8	7

Classroom Management	5.5	4.9	9

*Note. The lessons were approximately 40 minutes in length.

Tables 8 and 9 present the instructional functions observed in classes that applied the process skill activities alone. Teachers 7 and 8 made use only of the video materials to expose their students to science process skills. For teacher 7, increases were observed in information focus, (very slightly) in sequential flow, in elaboration, and in modeling. A decrease in classroom management utterances was observed simultaneously.

Teacher 9, another bilingual teacher, made use of the video materials in a classroom in which English was not used during instruction. Decreases were observed during the study period in the areas of information focus, elaboration, modeling (and slightly) in classroom management. A large increase in the sequential flow construct (from 42 to 65.9 per cent) of utterances was observed during the same time frame.

Table 8.

The instructional functions served by each teacher's classroom discourse. (Video alone*)

	Teacher 7		
	Pre-treatment Observation	Post-treatment Observation (1)	Post-treatment Observation (2)
Information Focus	15.6	8.3	16.6
Sequential Flow	66.2	74.4	66.5
Elaboration	4.0	8.7	6.7
Modeling	2.0	0.6	4.3
Classroom Management	12.1	7.9	6.0

*Note. The lessons were approximately 35 minutes in length.

Table 9.

The instructional functions served by each teacher's classroom discourse. (Video alone*)

	Teacher 8 (Bilingual)		
	Pre-treatment Observation	Post-treatment Observation (1)	Post-treatment Observation (2)
Information Focus	34.2	35	19
Sequential Flow	42	43.2	65.9
Elaboration	9.5	3	6.3
Modeling	8.2	12.1	3.2
Classroom Management	8.2	7.6	7.9

*Note. The lessons were approximately 35 minutes in length.

Discussion

The essential areas of interest in this study were in three areas: to examine changes in the elaboration construct, in classroom management, and whether an optimum combination of video/activity experiences produces viable changes within the above-noted classroom behaviors.

Table 10.

Summary of changes in teacher discourse

Treatment Condition	Elaboration (percentage change)	Classroom Management Interactions (percentage change)
Control (1)	-2.3	**-9.4**
Control (2)	-9.7	**-6.0**

Video/activity (1)	**5.2**	6.1
Video/activity (2)	**2.0**	0.6
Activities alone (1)	**0.5**	**-6.6**
Activities alone (2)*	**9.5**	3.5
Video alone (1)	**2.7**	6.1
Video alone (2)*	-3.2	**-0.3**

Bold indicates the desired direction of the change in terms of improved classroom experiences

*Bilingual classrooms

The findings of the study provide a number of points of interest for discussion. Before addressing the general considerations, the results with respect to the research questions will start the discussion.

The first research question looked for an increase in the presence of higher order thinking skills as a function of the experimental condition. This construct was captured by the *elaboration* category. There is *support* for this position during observation period. The changes observed in the elaboration construct support this position. Each of the experimental conditions demonstrated *some* increase in the presence of elaboration, save for one classroom. The combination of video materials and activities were identified with the increases in the construct of elaboration during the classroom interactions. In addition, the group that used the activities alone also demonstrated increases in the frequency of the modeling construct during the observation period. Among the video-only groups, an increase was observed in the English language group, but not among the Spanish-speaking group. As the videos were produced in English, this finding is not

surprising: This magnitude of this effect is compounded by the *decrease* in the frequency of this construct over time in the control group. In sum, there is *support* for the position that the use of the use of video materials, at least in terms of learners sharing the same language as the models on the videos.

The second research question examined changes in the role of classroom management concerns as a function of the instructional materials. From the data related to this construct, there is *no* support, at this point to suggest that the infusion of the materials at the beginning of the school year had lasting effects towards decreasing classroom management interactions. The greatest decrease in classroom management interactions, in fact, took place in the classrooms serving as the control for the investigation. In fact, the video models of the activities could be argued to have had a deleterious influence on classroom practices as demonstrated by the data presented. The only instance in which a positive change in classroom management interactions was associated with the use of the videotapes was with the bilingual class. The position with respect to this research question is that there is *no* classroom management value associated with the use of the video models.

The final research question sought evidence of an optimum combination of conditions regarding the use of the instructional materials. The data seem quite mixed in terms of the findings. The most definitive statement that can be made is that students benefited from the use of video, activities, and the combination of videos and activities when compared to the control group—in terms of the elaboration construct. Interestingly, the students in these classes also demonstrated the largest decrease in classroom management-related interactions. Perhaps the role of modeling among

students in the video and derived also from the classroom activities produces added stresses to the teacher's classroom interactions, resulting in a higher degree of management-type statements from the teacher. In response to this research question, no definitive answer has been obtained.

Teacher comments during post-study interviews provided both support for the use of the materials and insights into the materials. Typical responses included:

- Great model for the children
- Great model for teachers
- Discussions afterwards were very beneficial to children
- They showed real classes working
- Students [in the videos] explained the concepts
- Multicultural context [was helpful]
- Students were able to see examples of process skills being used by peers

These were consistent with what the developers of the materials had anticipated would be the strengths of the video materials. The intent of modeling found a role not only for the students, as had been anticipated, but in the comments of one teacher, in served the purpose of modeling inquiry practices for teachers as well.

The weaknesses of the materials, as recounted by teachers, included the following:

- There were quite a few times we had to stop and explain to students. Some concepts in the video were above their heads.
- There were not [any] weaknesses....I teach second grade bilingual, and ...the first one worked great, even for the non-English speakers

It is interesting that the teacher comments above, that "the first one worked great, even for non-English speaker" was made, as one of the desired outcomes of the project—that increases in elaboration-related interactions—was not observed in her classroom. Teachers in the experimental groups consistently found that the video materials helped to address their instructional needs, whether or not actual changes were observed. From this perspective, if the materials give the teachers more confidence to teach science, then instructional aides such as this might find an important home in classrooms where the teaching of science is a less-than-universal experience. This was further expanded upon by several teachers who stated that "more of the videos would be helpful" and a desire for the materials to be offered in Spanish, as well as a set for multiple grade levels. Related to the idea of more videos was one statement that more of the videos be produced so as to be used throughout the year, as opposed to the intensive, one-week use applied in this investigation. A further comment, echoing the request for more videos, suggested further that they be developed to precisely complement the existing curriculum, as opposed to a more general set of process skills videos.

Further investigation with materials of this sort are clearly warranted. Using the same materials in a modified setting—e.g., using the videos with the classes, but spacing the viewings several weeks apart might be helpful in producing more lasting effects. Too, conducting observations at more nominally "normal" times in the school year—removed from testing and spring break—might demonstrate more worth for the use of video modeling for process skills. Our work will continue to investigate the means by which to optimize the time and science learning of students.

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SITE-BASED PROFESSIONAL DEVELOPMENT: LEARNING CYCLE AND TECHNOLOGY INTEGRATION

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Project Goals and Objectives

Recent state and national reports verify the academic deficiencies of science students in this region of the country and call for changes in the way science is taught. The Nation's Report Card, released by Education Secretary Richard Riley, tested the science understanding of students in grades four, eight and twelve. Georgia students scored in the bottom 25% of students in the 40 states tested (Henry, 1997). In Georgia, 51% of the students scored at the "below basic" science understanding level. Moreover, 95% of African American students and approximately 95% of economically disadvantaged students (based on free or reduced lunches) performed below grade level in science understanding.

According to 1989-90 census data, African Americans comprise 30-50% of the population in 23 of the 50 Georgia counties surrounding Valdosta State University (VSU). In another nine of these counties, greater than 50% of the population is African American. Additionally, at least 30% of children (to age 18) live below the poverty level in 35 of these 50 south Georgia counties.

As a regional university of the University of Georgia System, VSU services the academic needs of the south Georgia region. This region contains a high proportion of minorities and students from economically disadvantaged homes. VSU must reach out to the science teachers of this area to improve their skills if their students are to become productive and contributing members of local communities.

According to the 1995-96 Georgia Public Education Report Card, the school district participating in this project contains a high percentage of African Americans (66%) and students qualifying for free/reduced lunches (78%). Two primary aspects of this project involved assisting middle school and high school science teachers of the district to 1) become knowledgeable and effective with an inquiry based teaching procedure (learning cycle) which is consistent with both state and national science education reform efforts (GIMS, 1996; NRC, 1996); and 2) obtain the necessary experience and skills with instructional technologies to incorporate them into the inquiry based teaching procedure.

Learning cycles consist of three phases: an exploration, a concept invention (also called term introduction) and an expansion. The exploration activities, usually laboratory experiments, provide students with the data needed to develop understandings of scientific concepts. The teacher-led concept invention phase follows the exploration. In this phase, students are guided in interpreting their data, thus inventing or constructing the science concept. As the students are developing understandings of the concept, the scientific terminology is provided. Following concept invention, the expansion phase provides for the application of the new concept; in other words, students organize the concept in relation to what they already know. The expansion phase of the learning cycle may include but is not limited to additional laboratory investigations, textual readings and/or audio visual aids. The learning cycle is an instructional practice that is designed to allow for a variety of teaching methods (e.g., demonstrations, class discussions, student presentations, field trips) and state-of-the-art science equipment (e.g., computers, CD ROM, video technology).

The learning cycle is a laboratory-based teaching procedure derived from the intelligence model of Jean Piaget (Lawson, 1995; Renner & Marek, 1990). Intellectual development,

according to Piaget (1964), takes place when students assimilate information from experiences (exploration), then accommodate the new information (concept invention). Previously held ideas or concepts must then be adjusted and organized with respect to the new information (expansion).

The results of past learning cycle institutes, sponsored by the National Science Foundation, have documented long term changes in the teacher participants (Marek, Haack, & McWhirter, 1994). The most significant finding from these studies is that 93% of the participating science teachers continue to use the learning cycle teaching procedure and/or curricula in their science programs nearly a decade after the institutes. Teachers stated that the learning cycle teaching procedure:

- extensively involved students in the learning process,
- produced deeper understandings and greater retention of concepts,
- developed students' thinking and communication skills,
- included teaching science process as well as content,
- was based upon learning theory and supported by empirical data, and
- made science relevant and meaningful to students.

We expected this project to have a similar impact on the teacher participants and students of these participants. In addition, this project was congruent with highly regarded science education reform documents. Described below are the major ideas of NSES and Project 2061 that were directly associated with this project.

National Science Education Standards (National Research Council, 1996).

Teachers of science should plan an inquiry-based science program for their students, guide and facilitate learning, engage in ongoing assessment of their teaching and of

student learning, and actively participate in the ongoing planning and development of the school science program. Professional development for teachers of science requires learning essential science content through the perspectives of inquiry; requires integrating and applying knowledge of science, learning, pedagogy and students; and must be coherent and integrated. As a result of activities in secondary science all students should: develop abilities necessary to do scientific inquiry and understandings about scientific inquiry, and develop understanding of science as a human endeavor and the nature of science knowledge. The program of study for all students should be developmentally appropriate, interesting, and relevant to students' lives; emphasize student understanding through inquiry; and be connected with other school subjects.

Science for all Americans: Project 2061 (American Association for the Advancement of Science, 1990). Learning is not necessarily a natural outcome of teaching. Cognitive research strongly suggests that students know less than we think they do following instruction. The quality of student understanding should be emphasized rather than the quantity of information presented. Students must construct their own meaning regardless of how clearly teachers or books tell them things. The dependence of most people on concrete examples of new ideas persists throughout life. Students learn most readily about things that are directly accessible to their senses - tactile, kinesthetic, visual, and auditory. Teaching should be consistent with the nature of scientific inquiry. Science, mathematics and technology is defined as much by what is done and how it is done as it is by the achieved results. Students must have experience with the thoughts and actions prevalent in these fields. Teachers, therefore, should start with questions and phenomena that are interesting and familiar to students, engage students actively,

concentrate on the collection and use of evidence, provide historical perspectives, insist on clear expression, use a team approach, not separate knowing from finding out, and de-emphasize the memorization of technical vocabulary.

The key concepts described above from the NSES and Project 2061 formed the foundation of this project primarily through the use of the inquiry based, learning cycle teaching procedure. It places the students at the center of their learning experiences, encouraging them to engage in explorations, form new understandings and relate those understandings to other concepts. Additionally, several other important dimensions were incorporated into this project. These included the extensive use of technology in the learning cycle development sessions, the use of experienced inservice teachers to model inquiry based science lessons, establishment of an Advisory Panel, and extensive follow up and teacher support activities.

Proposed Activities

An Advisory Panel was responsible for the planning and implementation of the project. The Panel consisted of a science teacher, scientist, educational technologist, and two science education professors (one middle school and one secondary). The project included three phases. The first phase of the project, Exploration Phase, was designed to allow the teacher participants to explore the theoretical underpinnings of the learning cycle and experience the operation of a variety of instructional technology equipment available to them at their schools. The second phase, Application Phase, was designed to allow teachers to construct learning cycles and integrate technology into their curricula. The third phase of the project, Follow Up Phase, was one in which teachers applied the new found information and skills to their science curricula.

I. Exploration Phase

Twelve middle school and secondary school science teachers from the district participated. For a period of one week in the summer, these teachers met five days from 9am to 3pm at the district high school or middle school. During the first one and a half hours of each day, teachers met in seminar sessions. These seminars, led by science education professors, were devoted to examining a) the structure of science; b) the nature of human learning; and c) authentic assessment strategies for student evaluation in learning cycle curricula. The remainder of each day was spent in two laboratory sessions led by other members of the presentation team (teachers, scientist, education technologist). These sessions included technology laboratories, designed to familiarize teachers with the use of a variety of educational technologies available to them (e.g., computers, video technology) and how to incorporate these into their curricula; and science laboratories modeling the learning cycle teaching procedure led by inservice middle school and high school teachers experienced in the inquiry teaching procedure. The technology laboratories were led by the technology specialist or inservice teachers experienced at incorporating technology into the classroom. An important point to be made here is that each learning cycle investigated (an) important and easily recognizable scientific concept(s). That fact permitted the teachers in the workshop to review science content while they learned how to teach that content using learning cycles. A scientist was on staff to monitor the accuracy of the science content taught through the learning cycle demonstrations and acted as a science content reference for the remainder of the staff and teacher participants. This phase of the project required teachers to meet with project staff at least 30 hours over the five-day period.

II. Application Phase

This phase began after the first two weeks of the start of school in August, 1998. Teacher participants met with the project staff every alternate Saturday for 8 weeks from 10am to 3pm (four total sessions over an eight-week period). These meetings took place in a science laboratory at the district high school or middle school.

During the Application Phase, teachers received a copy of the learning cycle science curricula of their choice - biology, chemistry, physics, general physical science, life science, earth science. In addition, all teachers brought their current science curricula so they could use the learning cycle curricula as a model to integrate with their science curricula. During each of these sessions, teachers in partnership with each other and the project staff, modified two weeks of their science curricula into inquiry based lessons. Successes/difficulties associated with implementing this inquiry-based curricula in their own science classrooms were discussed.

This phase of the project required teachers to meet with project staff at least 20 hours over the four meeting days. Communication with staff members, such as the scientist for questions pertaining to content, was encouraged through the use of electronic mail.

III. Follow Up Phase

The Follow Up Phase occurred through the remainder of the fall semester and throughout the spring semester. The Exploration and Application Phases of the project allowed teachers to accommodate the inquiry based curricula and its theory base; but sound understanding comes with using the learning cycle in their science classrooms during the ensuing school year. Therefore, follow up meetings were a significant part of the project and occurred in many forms.

A member of the project staff observed each teacher in their classroom four times during the Follow Up Phase. These four observations occurred once during each of the months of

November, February, March, and April. Following each observation was an individual meeting between the teacher and staff member to discuss the implementation of the inquiry teaching procedure, incorporation of technology, assessment, or other factors associated with the curricula.

In addition to these individual observations were two meetings with all teachers and project staff members to share successes/difficulties and to brainstorm solutions to problems any teacher may have encountered. These meetings took place after school from 3-5pm once in February and again in April.

The follow up part of this project resulted in at least 12 hours of contact time between each participant and the project staff. Total contact time with each teacher over the course of the project was estimated to be at least 60 hours. Teachers received six staff development units and a stipend of $100 for participation in this project.

Description of Participants

Teacher participants in the proposed project were middle school and high school science teachers from a rural school district located in south Georgia. All were currently certified to teach science or were seeking certification to do so. Science department heads for the high school and middle school were a part of this group of teachers and participated in the project. One school district was chosen in order to provide participants with a strong collegial support network.

Evaluation Procedures

A thorough evaluation plan was implemented to assess program effectiveness with respect to teacher and student outcomes. The evaluation plan had substantial formative and summative aspects and placed particular emphasis on the domain of cognitive and affective development. Within these two domains, the evaluation instruments primarily measured: teacher attitudes and pedagogy; and student attitudes toward science and understanding of science concepts in general.

Results

Results of open-ended questionnaires administered to the teacher participants at the end of the school year indicated they felt the use of the learning cycle teaching procedure and integrating technology had important impacts on their students. Representative responses from the teachers included comments such as, "Students have begun to ask "why?" They have begun to look forward to class instead of dreading science/math activities." "My students have begun to think for themselves, and come up with their own explanations for various situations/events." When asked how the learning cycle approach has affected their interaction with students, the teachers responded that they enjoyed a more positive and productive student/teacher relationship since implementing the learning cycle in their classrooms. Typical comments included, "The learning cycle has helped foster a good working relationship in which we learn from each other. Creativity is at an all time high." "More movement and talking between us, but much more interest and responsibility on their part." "The learning cycle has had a positive effect on my students. They enjoy the class more and look forward to activities in class."

When asked about their self-efficacy as a result of incorporating the learning cycle and technology in their classrooms, responses from the teachers indicated they felt they were doing a

better job as a result of the project. Comments included, "More effective and with renewed interest. I'm out of a rut and thankfully so. The students enjoy the day to day change." "My students are retaining more information, which suggests to me that I am more effective in the classroom. My expectations have increased." "I feel more like the sign in my room which says that the teacher in this classroom is a highly trained professional with the necessary skills and motivation to manage an effective learning environment."

Discussion

This project involved middle school and high school science teachers in a 60-hour collaborative project that spanned an academic year. The primary emphasis of the project was the incorporation of the learning cycle teaching procedure and instructional technologies available to the science teachers in the participating district.

Results of the project indicated that teachers felt that using the learning cycle and incorporating technology where appropriate influenced current students, compared to those of past years, to exhibit greater interest in science, ask more questions of the teachers, cause less disruptive behaviors, and perform better on science examinations. The teachers themselves indicated a greater self-efficacy, and a renewed interest in teaching.

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PROFESSIONAL DEVELOPMENT AS INQUIRY: THE ROLE OF FORMATIVE ASSESSMENT IN PROFESSIONAL DEVELOPMENT

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Background

Professional development efforts in science education have emphasized the workshop experience where teachers and professional developers alike learn new skills in order to infuse their practice with current thinking. These experiences are often "one size fits all" (Ball & Cohen, in press) but seldom are situated within an ongoing context of professional practice. It can be argued however that research on teaching practice is best served by "helping teachers reflect on their own beliefs, personal knowledge, and practice" (Richardson, 1994, p.9). Such reflective practice can be advanced by both in-service and pre-service teachers and by professional developers by using formative assessment as part of ongoing research into teaching and learning (Ash, Tucker, Austin, Ferguson, Kraft, & Heller, 1999).

Much has been written about the importance of formative assessment for gaining better understanding of student progress (Black & Wiliam, 1998), but less attention has focused on the efficacy of formative assessment as a mechanism for professional development, specifically for enhancing teacher pedagogical strategies and as a sensitive tool for self-reflection. Ash, Levitt, and Tucker have found that formative assessment is a powerful motivator for reflective change in teaching science via inquiry. Their work is situated in the context of practitioner-based research where teacher and professional developer together collaborate in ongoing formative assessment of teaching practice.

The work of the three authors vis-a-vis formative assessment, inquiry, and professional development can be characterized as teacher and professional developer inquiry into practice so that the "practitioner draws inferences based on his or her own experience and applies it in context" (House, Mathison & Taggart, 1989, p.15) in order to inform pedagogy.

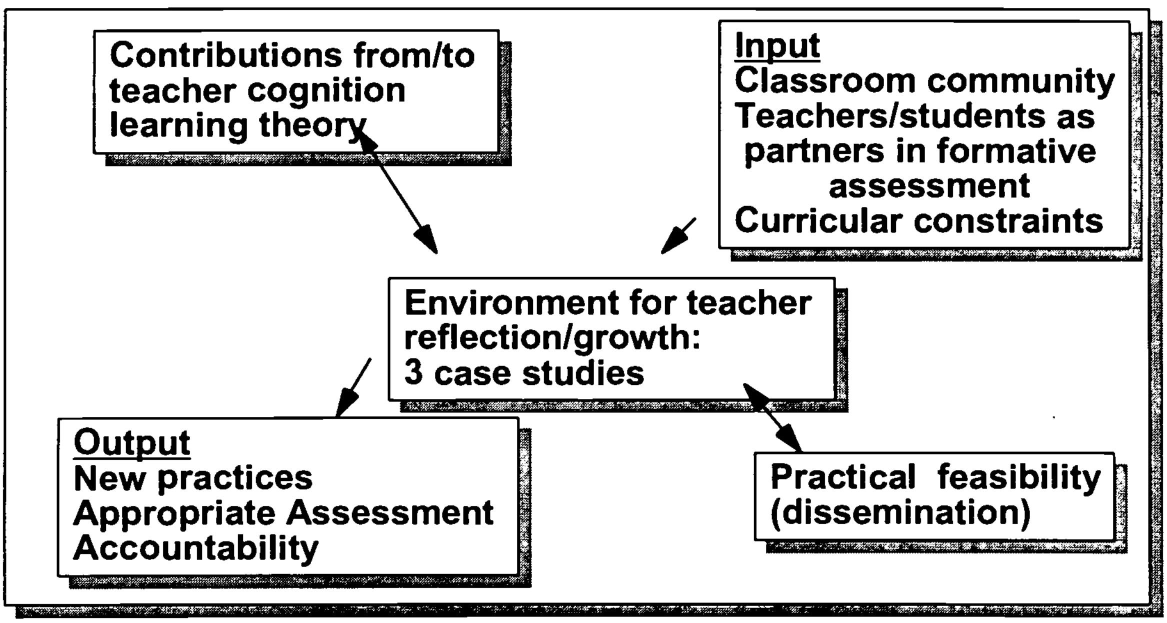
Theoretical underpinnings

Vygotsky (1934/1986) and the notion of the zone of proximal development, as well as the work of Newman, Griffin and Cole (1989), provide the theory that informs this work. We propose that a reciprocal and mutual interaction occurs between the 'teacher and learner' as they work together so that that each is changed within a zone of interaction between them. In short, both the 'teacher' and the 'learner' inform the other in substantive ways so that both act as teacher and learner in mutual appropriation of ideas and actions (Brown, Ash, Nakagawa, Gordon, Rutherford & Campione, 1993).

We suggest that formative assessment (assessment that informs learning) (harlen, 2000)occurs within zones of proximal development. "A zone of proximal development is the region of activity that learners can navigate with aid from a supporting context, including but not limited to people. It defines the distance between current levels of comprehension and levels that can be accomplished in collaboration with people or powerful artifacts. The zone of proximal development embodies a concept of readiness to learn that emphasizes upper levels of competence" (Brown, et al., 1993; Vygotsky, 1934/1986). Formative assessment can be used by both the learner and the teacher to understand the gap between the learner's current and potential levels of understanding. In turn, the teacher and the learner can plan for strategies that will help the learner move toward their upper level of understanding.

We argue that there are numerous parallels between the use of formative assessment by teachers and by professional developers. In both cases, the process is a self-reflective one. In classrooms, teachers find that formative assessment propelled their own professional development in tandem with the development of their students. In many ways, teachers were self-monitoring their practices through the lens of assessing a child's understanding. The very same thing can be said when we examine cases of professional developers working with teachers in either preservice or inservice settings. Their increasing understanding of student work informed a mutuality of perspective in which both the teacher and student grow according to their abilities. The theoretical perspective taken from Vygotsky (1934/1986) suggests that learning is interpreted as part of a social cultural process where the interaction between the entities is the focus rather than either of the actors per se.

Figure 1
The Environment for Teacher Reflection and Growth



Adapted from Brown, 1992

In Figure 1, the teacher is at the center of an environmental system that includes constant interaction with other elements so that each action by the student/learner and teacher informs other parts of the system.

Working in the Zone of Proximal Development (ZPD)

We interpret this ongoing and dynamic change with the system as occurring within the zone of proximal development (zpd). As teachers (or professional developers) look at learners' work in more detail, they begin to see a 'mismatch' between what they expect the student can actually do and the original purpose of the material taught. The more closely the teacher uses formative assessment to advance student learning, the more apparent these differences can seem. These discrepancies highlight the need for consistency between expected and actual student understanding. The teacher/professional developer must either change expectations or change teaching practice. This striving for consistency informs teachers' practice.

As professional development, the use of ongoing formative assessment allows the teacher to delve into his or her own practice in a way heretofore not considered. The use of new methodologies, such as video as reflective tool, allows teachers to better understand their role in the complex mutual interaction with the student. Using formative assessment with students allows the teacher to reflect critically on their own understanding, as well as to reflect on their own practice, as part of a unit of mutual growth. This feedback loop of student change and teacher change propels each forward.

Based on her work at the Exploratorium with teachers using formative assessment, Ash has outlined a proposed developmental trajectory of teacher growth over time. This trajectory is outlined briefly in the following four steps:

1. Examine student work closely.

2. Begin to see the gap between reality and expectation, either in expectation, ability or overall goals.

3. Self-reflect, looking at own practice to begin to adjust pedagogy, either the requirements of the task, providing student aid or reevaluating goals of task.

4. Continue to self-reflect and adjust to constrain tasks and/or expectations according to the student's ability, which moves student forward towards desired conceptual goals in ongoing mutual growth for the student and the teacher.

Three Case Studies

Three cases are presented in this paper to illustrate the use of formative assessment as professional development. Each case is presented through the framework outlined by Ash to describe the growth experienced by the teachers. The three cases include

1. Teacher researchers simultaneously examining their own change and student change using student questions as a focus.

2. Teacher mentors and pre-service teacher collaboratively examining the pre-service teacher skills' to inform each teacher's practices.

3. Teacher researchers using student work as a focus for professional development.

Case 1: Using questioning as the focus for formative assessment in teacher research

As part of a teacher research group working at the Exploratium (CA), Ash studied elementary teachers engaged in classroom-based research using inquiry to teach science. In her analyses of teacher change, Ash emphasizes the use of teacher questioning (van Zee, Iwasyk, Kurose, Simpson & Wild, 1997) as a mode of formative assessment of student understanding. Doing formative assessment through questioning allows the teacher or professional developer to

reflect critically on their students' understanding as well as to reflect on their own practice as part of a unit of mutual growth. This feedback loop of student change and teacher change propels each forward. Each of the participating teachers examined students' work closely, specifically students' development of the skill of asking questions as the focus of their inquiry.

Examining students' work more closely. The first step includes teachers looking closely at student work via a variety of methodologies. In this case, teachers examined student questions.

> I practice active listening to the children's responses, since their questions often come in the form of statements. Then it's up to me, the teacher, to help turn their statements into investigation questions by asking things like "Do you mean...?" or "Is this what you are asking?" I acknowledge and record all of their questions.
>
> While watching the children explore, I encourage them to ask questions about whatever seems curious to them. Because students often have difficulty asking questions, I support them in various ways. For example, I do a lot of modeling. I also ask a lot of open-ended questions, such as: "Can you tell me what you are trying to find out with this instrument?" or "Is that what you expected to hear?" Eventually, the children get used to hearing the kinds of questions that can lead to investigations. Teacher 2, WC, 2nd grade

Seeing the gap between reality and expectation, either in expectation ability or overall goals. As teachers observed students' ability to raise questions, inevitably they found ways to assess them in order to devise a way to improve their development.

> I always start by modeling how to ask questions that can be investigated, and how to look at a list of questions and eliminate some or re-word some that can't be investigated easily. By inviting students into the process of recognizing questions that can be investigated, I

found that I help them to be better questioners, yet to also do investigations based on their questions and get to the content I am responsible to teach. Teacher 2, WC

Explicit lessons modeling questions meeting the criteria for rich investigations helped students focus and evaluate their questions. The group process of developing and evaluating questions led to more complexity and richness. Guiding students to look back at questions after investigations were reported helped them learn from their experiences and those of others. Teacher 4, JH, 5th grade

In designing investigations, I start with one of the questions and show the class how to turn it into an investigation by identifying the variables and then isolating one variable. Then students expanded that variable and decided how all the others could be kept constant. The students then used their own question to turn into an investigation. They write their investigation in their logbooks, record the procedure they might use, list materials and form a hypothesis. Teacher 3, JL, 4th grade

Begin to adjust pedagogy; either the requirements of the task, providing student aid or reevaluating goals of task. As their assessment of students' understanding increased, they began to match next steps to these students' perceived needs in a formal and explicit way.

Allowing adequate refection time following each exploration promotes the analysis that will lead to questions developing from genuine curiosity. Through my experiences, I found that the most authentic questions, those arising from true curiosity, were to be captured during these explorations or in the reflections that followed. Teacher 3, JL

It would be valuable to explore the optimum mix of guided explorations and self-planned investigations. These children had very few self-planned experiences: just one at the end of each major unit. The guided experiences seem critical to developing background and opening the content to them to provide a context for questioning. The self-planned experiences are very time and energy consuming, and I found it difficult to find the time for them. Looking back, I sense that the self-planned investigations were one of the most influential factors in making the process of questioning have meaning for them. The simple guidelines and rubric posted in the room helped students understand that there are levels of questions. It seems that more of these experiences, even short, two-day investigations, would promote more skill in questioning. Teacher 4, JH

Beginning to constrain tasks and expectations according to students' ability in ongoing mutual growth and that lead towards desired conceptual goals. Growing more explicit in their ability to help shape students' development, teachers understood that they could constrain the task to maximize understanding in certain areas.

After the explorations with sound we have generated many questions. We have reworded some of them, and there are many that overlap in how they relate to the concepts. So I have learned to constrain and refine the questions. I group their questions into similar categories. So if initially there were 12 or 15 questions about sound from the children, I do an intermediate step to group some of these questions because I know what concepts I need to teach. I work together with the students to re-word some of the questions so the students still have ownership over the questions they get to choose to investigate. We do this by doing a lesson on how to sort questions into different groups.

By working with the children to narrow down those 12-15 mixed questions to about 4 or 5 more directed ones, I know I will be able to draw the content out and to make it more meaningful when the children have discussions at the end of their investigations. I have learned over the years that by narrowing down and re-wording some of their questions, the discussions at the end is richer, and although the children are working on different questions, they discover many of the same concepts because the questions overlap.

This way, children are more self reflective when they ask questions, they know what questions are, which questions will lead them to doing tests, which question would be more like a reference kind of question, which questions we can easily answer with a yes or no, which ones that maybe are too big because we don't have the materials or seem too difficult unless we can change it somehow. Teacher 2, WC

Case 2: Using formative assessment of the teacher candidate as professional development for the mentor teacher and the teacher candidate

In a different context, Levitt worked with teacher candidates from three universities (Duquesne University, Carlow College, and the University of Pittsburgh) who engaged in formative assessment of their developing skills of teaching through inquiry. Collaboration between the teacher candidates and their mentor teachers as professional developers around five specific skill and knowledge areas deepened all teachers' understanding and practices of inquiry in the classroom.

During the 1999/2000 school year, thirteen teacher candidates and their cooperating teachers participated in a field test for an Inquiry Science Endorsement for the teacher candidates. The Inquiry Science Endorsement was initially conceived and designed to assess the

teacher candidate's ability in five skill and knowledge areas of the teaching of inquiry science. However, the Endorsement became a vehicle for self-examination and reflection for both the teacher candidate and the cooperating teacher, resulting in meaningful professional development for both participants as related to the teaching of inquiry.

A significant part of earning a certification is the evaluation process. Much has been written about the evaluation of teachers (Danielson, 1996; McGreal, 1983; Peterson, 1995). Traditionally, in the supervisory relationship, the assessment is summative in nature, not allowing for feedback and subsequent growth. However, adult learning theory provides evaluators with the framework for designing evaluations that are both formative, allowing teachers to learn from the evaluation process, yet are ultimately summative, providing information for the purposes of making decisions about the teacher candidate. In guiding teacher candidates, it is important that evaluation be oriented toward growth of the individual, meaning it should be formative in nature so that the teacher candidate can learn from the process and continue to develop towards established competencies representing exemplary performance.

What emerged in the research of 1999-2000 was a deepening of understanding of inquiry for both the teacher candidate and the mentor teacher. As stated earlier by Ash, "doing formative assessment allows the [mentor] teacher to reflect critically on their own understanding of inquiry, as well as to reflect on their own practice, as part of a unit of mutual growth. This feedback loop of teacher [candidate] change and [mentor] teacher change propels each forward." A case study of Barb, the mentor teacher, and Jen, the teacher candidate, demonstrated this reciprocal growth that resulted from their participation in the process.

At the beginning of the semester, Barb and Jen discussed each skill in the Endorsement in order to come to a mutual understanding of the skill and the related criteria for achieving

mastery. Barb stated that reviewing each skill with Jen "heightened her awareness" of each element of the skill area. After reviewing the document, she found that while she was teaching she would recognize a specific skill that she and Jen had discussed and often wanted to stop in the middle of a lesson and point something out that she had done that was an example of the criteria. Sometimes, she would pull Jen aside during the lesson she was teaching to reflect on the actions she had been demonstrating. She believes that participating in these conversations with Jen and modeling the skills "pushed buttons" in her own practice in areas that she may not have otherwise explored, thus causing her to develop these skills even further.

For Jen, as she spent time observing Barb teach, she asked herself "How did I see this skill in Barb's teaching?" After the lesson, she and Barb discussed the lesson, providing opportunities for Jen to reflect on and learn from someone else's teaching. When it was Jen's turn to teach, she felt her lessons flowed "more smoothly" and that she knew "this is what I have to do and what I have to do next" because the skill had been modeled for her and specific criteria had been established that provided her with a framework for her lesson. Ultimately, Jen said she was more "in tune" to the different skills necessary for teaching through inquiry because her reflection centered around her work in an actual classroom, rather than in the contrived context of a methods class. Therefore, the teacher candidate's growth was grounded in the actual events of teaching. The formative assessment that occurred in the context of the Endorsement made the teacher candidate, as well as the mentor teacher, more aware of their practices and enabled both of them to extend their understanding of and subsequently modify their practices.

<u>Examining students' work more closely.</u> Applying Ash's trajectory to the teacher candidate/cooperating teacher relationship reveals similar patterns of action that result in professional growth. For this relationship, the process begins with the mentor teacher examining

the work of the teacher candidate more carefully. The Endorsement provided a lens for thoughtful analysis of the teacher candidate's practice, describing, interpreting, and critiquing events of teaching and learning. According to Barb, the Endorsement served as a neutrally agreed upon set of standards and validated the important skills of inquiry while, at the same time, increased the teacher candidate's comfort with the skills because they had been determined by "others." This minimized the dilemma often faced by the teacher candidate between teaching according to what they learned in courses and teaching in a style that pleases the mentor teacher. Initially, Barb observed Jen's overall teaching ability in science while keeping the required skills in the forefront of the observation.

<u>Beginning to see the gap between reality and expectation, either in expectation ability or overall goals.</u> As a result of the observation and subsequent discussion, the mentor teacher and the teacher candidate began to see the gap between the teacher candidate's performance and the criteria as outlined in the Endorsement, either in expectation, ability or overall goals. For example, Skill #3 of the Endorsement is "Implementing an Inquiry Lesson." Within this skill, several of the criteria include the use of questioning as a strategy consistent with the use of inquiry. Evidence that the student teacher has mastered the skill includes posing questions and using open-ended questions to further student understanding. In reflecting on several of Jen's lessons, Barb and Jen determined that Jen was not yet demonstrating this evidence. According to the trajectory, the cooperating teacher should then look for ways to help the teacher candidate improve. In this case, the Barb referred back to lessons that Jen had observed her teach to provide examples of the criteria in action. Additional modelling of the questioning skills, by Barb, in science and in other subject areas, served as an intervention strategy.

Beginning to adjust pedagogy; either the requirements of the task, providing student aid or reevaluating goals of task. Because the skills of the Endorsement can be demonstrated any time during the student teaching semester, the teacher candidate has the opportunity to continually improve their skills. Jen taught additional science lessons focusing on the skill of questioning. At this point in the trajectory, the mentor teacher begins to adjust pedagogy either the requirements of the task, providing student aid or reevaluating the goals of the task. Because the goals are standardized for all of the participants, the goals of the task could not be modified. Therefore, the subsequent course of action for the mentor teacher was to adjust pedagogy and/or to provide additional aid to the teacher candidate. This aid can come in the form of very specific suggestions that help the student teacher to bridge the gap between their original skill level and the desired goal. For example, Barb provided Jen with a written guide for developing specific types of questions. The guide provided question stems that Jen could use to plan the questions she might ask during her lesson. Jen used this guide as the next step in her development of this skill.

Begin to constrain tasks and expectations according to students' ability in ongoing mutual growth and that lead towards desired conceptual goals. To further promote growth, the mentor teacher begins to constrain tasks and expectations according to the teacher candidate's ability. In Jen's case, through reflection on her lessons, she and Barb agreed that Jen needed to reexamine specific questions that would "open up" the lesson and move away from "dead end" questions, as Barb called them. Barb became more aware of her own use of these questions and noted them to Jen in the course of her lessons. Then, with more planning for open-ended questions, Jen was able to integrate these questions into her lessons and encourage participation from more students through her developing skills.

Case 3: Looking at student work as formative assessment in ongoing professional development in classroom practice

Tucker, a professional development specialist in Cambridge (MA), used a series of protocols that allowed teachers to look at student work in structured ways. As a result, she suggested that using formative assessment to look closely at student work deepened the teacher's understanding of the need to change practice in order to improve student learning. Again, in this case, formative assessment was used as a vehicle for professional development.

Once more, parallels exist between Ash's trajectory and the professional development of Annette, one of the teachers participating in Project ASSIST. Project ASSIST was a three-year program around inquiry based learning and collaborative assessment of student work.

Examining students' work more closely. Initially, teachers examined student work closely. In Project ASSIST, the student work was examined collaboratively with colleagues. Annette believed that examining the work collaboratively opened her eyes "a little bit more." She described an instance when she examined a piece of student work and did not feel that the student demonstrated understanding, but when a colleague looked at the same piece of student work, they saw some indication of understanding that perhaps she had overlooked. The example Annette used was teaching students about scientific drawings. At this point, she began to adjust her thinking: "The students are not doing anything wrong. They're there just waiting for the opportunity..." In the following stage, Annette uses the feedback from her colleagues and her own judgments to examine the gap between her expectations and the reality of the student's work.

Begin to see the gap between reality and expectation, either in expectation ability or overall goals. According to Annette, the purpose for closely examining student work was to "see what a student put down after a lesson compared to what we wanted." Examining the students' work compelled Annette to "really look at what a student was learning about an

experiment…and then just being better able to plan the next lesson, and be O.K, ready for it." The example she continued to use was teaching the students about scientific drawings. Annette described the students' tendency to "fictionalize" the drawings rather than include an accurate depiction with scientific information and appropriate labels. In Annette's words, she "began to see the gap because teachers are not always as clear as they think they are being. Sometimes it is not really clear to the teacher. O.K. what do I really want them to get out of this lesson? I can't expect them to get anything from this unless I'm clear about it. So if I'm clear about what I'm hoping they pick up through this experience, then I have a better chance for them to be clear about it." This clearly demonstrates her profound awareness of the gap that existed between the teacher's expectation and the students' reality.

Begin to adjust pedagogy; either the requirements of the task, providing student aid or reevaluating goals of task. As a result, Annette described several strategies she had for adjusting her pedagogy to help move the students forward. First, Annette described how she modeled and discussed how scientists use these drawings. She did one drawing together with the class, modeling "how scientific information is part of the drawing, not "fictional" drawings." She instructed her students to draw the picture so someone else, like the principal, would understand it. She provided specific questions for students to answer, for example, about their worm. Furthermore, she stated, "I had to be far more thoughtful about what I was teaching." She described how she used the opportunity in writing workshop to improve the recording of information, to encourage students to put accurate information in a format that is understandable. In addition, Annette employed a strategy involving her colleagues. Using her colleagues, she asked the question "Can you help me think about how I might get this child from point A to point B?" further adjusting her pedagogy to help students.

Begin to constrain tasks and expectations according to students' ability in ongoing mutual growth and that lead towards desired conceptual goals. Annette provided several examples of constraining the task and expectations according to the students' ability. "Rewording a question, using different technology, if it means putting them at a computer or putting them in front of a tape recorder or having someone scribe for them, that you come to assist their particular need and they feel successful because they're able to get everything out and people know what they know about science" are some of the strategies she outlined.

Annette described the ongoing mutual growth that she experienced throughout her participation in Project ASSIST. "[Formative assessment] becomes your new pedagogy. An amazing opportunity for reflection...I think it's clearly a teacher reflection time, O.K. reflect on your own pedagogy. Consider what you are teaching. Consider the learning styles. Consider the assessment tool...I'm assessing the child after each lesson so that I don't have to wait until the end or the until...How can I then in the next lesson help this child to get this idea in the next lesson?"

Tucker (1999) suggests that: "looking at student work to understand what students understand collaboratively met the characteristics of the best professional development." These characteristics include teacher choice and control; complex work within a safe framework; multiple viewpoints; concrete; and relevancy.

1) Teacher choice and control

Not all teachers had the same belief systems. Teachers [had] the structured and safe environment that the protocol created [and] could hear and discuss other ideas. They could also choose [from] among those ideas that they wanted to test, in whatever way they wanted to test them;

2) Complex work within a safe, framework

Changes in thinking about objectives and designing assessments to reveal particular student understanding presented required greater depth of understanding and presented greater risks;

3) Multiple viewpoints

These small successes seemed to bolster teachers' confidence in their ability to affect change in student performance. Changes in thinking about objectives and designing assessments to reveal particular student understanding presented required greater depth of understanding;

4) Concrete

It forced teachers to think more deeply about what they wanted students to understand and how they could present evidence of student understanding to others.

5) Relevancy

As they [teachers] struggled to discuss student work objectively, teachers began to see more of what students actually revealed in their work and to question how it aligned with their teacher objectives. Many realized that they had no deep objectives of their own but to "teach" the science unit or lesson. The lack of clarity and understanding of the science concepts by the teacher affects student learning.

Using formative assessment as professional development incorporates these best practices of effective professional development. Furthermore, these five characteristics are readily apparent within the trajectory outlined at the beginning of this article.

The same occurs for professional developers who examine teacher change over time. But in this case, the inquiry is into teacher change. According to Tucker (1999), "Using formative assessment to look closely at student work student protocol "worked to deepen the teachers' understanding of the relationship between teaching practice and student learning

and to use change in teaching practice to improve student learning. It worked for me [Tucker] in a similar way – to deepen [my] understanding of the relationship between teacher practice and student learning and the relationship between professional development and teacher change." The elements of the inquiry/formative assessment cycle remain constant except that in each case the action taken depends on the kind of evidence gathered by the researcher. In the cases of student and teacher, there is an element of active reflection on work done and action taken to affect change.

Table 1 Parallels Between Student Inquiry and Teacher Formative Assessment

Inquiry Process	
Student inquiry	Formative assessment
• Explore materials and/or behaviors (concrete and observable)	• Examine record of student performance or work (concrete and observable)
• Raise investigable questions	• Raise investigable questions (including what and how to assess)
• Plan, test ideas, experiment (with materials, creating whatever jigs and tools needed to carry out the investigation)	• Plan, test ideas, experiment (with student work, creating assessment prompts, recording forms, or situations needed to carry out the investigation)
• Collect and analyze data (measurement and/or observations, creating graphs, tables, or charts, and tools as needed)	• Collect and analyze data (student work, creating record keeping and analysis tools as needed)
• Draw conclusions backing them with evidence of data.	• Draw conclusions backing them with evidence of data.
• Raise new questions	• Raise new questions

Discussion

Taken together, these three cases of professional development move beyond the current interpretation of professional development in the sciences and mathematics (Loucks-Horsley, Hewson, Love & Stiles, 1998). The particular relevance of this work to science teacher professional development lies in better understanding how formative assessment acts an effective strategy for ongoing professional development for a wide range of teaching, from pre-service to experienced teachers, to university personnel. The use of formative assessment is a strategy that models reflective practice and mutuality of perspective based on Vygotskian theory.

In the three different contexts presented in this paper, teachers and professional developers found that formative assessment propelled their own professional development in tandem with that of their students and/or peers. A developmental trajectory was proposed and developed based on the data from the three science education reform efforts. This process assumes teachers grow professionally when they are aware of how they are actually teaching and have an opportunity to study and modify their practices in the interest of student learning. Examining the subtleties that distinguish teaching science through inquiry, the professional developer and the teacher, the mentor teacher and the teacher candidate, and the teacher and student experience ongoing mutual growth that leads toward the desired goals.

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A COMPARITIVE ANALYSIS OF SCIENCE TEACHER EDUCATION IN GLOBAL COMMUNITIES

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As we enter the 21st century, several issues nee to be addressed if we are to provide professional development for science teachers that is successful, appropriate, effective and have a long term effect. The first issue is diversity – the need to educate an increasingly diverse student population with different cultural perspectives, experiences and expectations of education, different styles of learning and behavior, and parents who bring differing views of teaching and learning to our schools.

Another major issue is enhanced goals as proposed by national standards and the global move supported by the UN at the Beijing conference towards scientific literacy for all. Achievements of these goals require that teachers know their subjects in-depth and know how to teach them to diverse learners. The attitudes skills and knowledge required by teachers to achieve this new vision for science education is both broad and deep requiring science teacher educators to re-evaluate their models for professional development, since clearly the traditional models for professional development are inadequate for helping teachers to achieve the goals of scientific literacy for all.

As noted by Loucks-Horsley et al. The current state of professional development includes:

(a) Significant numbers of teachers who have few or no professional development opportunities;

(b) A large percentage of the opportunities in the form of workshops, courses, and institutes that may not be appropriate to the learning goals or provide sufficient support over time for teachers to apply what is learned in classrooms;

(c) A focus on individual development, one teacher at a time, without attention to organization development; and

(d) Some pockets of innovation but with minimum means for greater impact both within their own system and beyond. (Loucks-Horsley, et al. 1998).

Designing and implementing meaningful, effective professional development initiatives for science education is complex and fraught with many barriers and pitfalls. However, there exists a strong knowledge base and a great deal of consensus about what constitutes effective professional development, unfortunately there is a gap between knowledge and practice.

According to Loucks-Horsley et al (1998) one major reason is the lack of rich descriptions of effective programs constructed in various contexts addressing common challenges in unique ways.

Purpose

This paper is intended to provide a description of the practices and issues that arise during professional development of science teachers in a global context. It is both a description of science teacher's education models and a discussion of the issues that arise during professional development of science teachers. It provides a rich description of the socioeconomic and cultural contexts and challenges in teaching science, providing descriptions by experiences professional developers and researchers about ways in which they address the many barriers to effective professional development.

Professional development in science education is an area that has, to some extent, been investigated in isolated units in specific countries. However, we have not, as educators done a comparative analysis of what issues and perspectives arise during professional development for the teachers. The following will provide a comparative analysis of what issues and perspectives arise during professional development for teachers of science in many parts of the world.

The paper will investigate the following questions:

- Are there differences and similarities in the way professional development is conducted in global communities?
- What are some of the contextual factors in professional development?
- What are some of the cultural issues that arise?
- Are there equity issues that have to be considered as science teacher education models evolve?
- What science teacher education models are being used globally?
- What are the measures of success?
- Are these models country specific, or can successful models be transposed from one country to another?
- How can we share our successes and alert others to the courses of our failures?

This paper will address these and other issues and will serve to expose science teacher educators to a global view of professional development and to some of the research, which has been conducted during the development of these models. Each section addresses specific issues in one or a group of countries. The authors are either science teacher educators who are residents of the country of have been involved in research studies in these countries.

A Global View of Professional Development

England and Indonesia

The role of in-service professional development of science teachers in large-scale changes in teaching practice is examined. Educational research has been remarkably successful in showing how the fundamental work of psychologists, philosophers, and sociologists can be translated into practical classroom procedures, which improve the immediate quality of learning and the long-term effects on students' life chances. This work has, however, too often been limited to lab school experiments conducted at a few sites and has failed to take off into large-scale implementation – for example through adoption by school districts. Blame for this failure of the educational system as a whole to realize the benefits of well-researched practice may be placed on: the researchers, concerned with academic publication and moving on to the next new work, or on their failure as publicists; on the conservatism of teachers and school managers; on short-sightedness of politicians concerned more with elections a couple of years away than with benefits to the society which may not show up for 10 years; or, inevitably on lack of funding. At different times and in different places probably all of these accusations can be justified, and may be summarized as the inertia of the system, like a massive tanker whose direction cannot be changed by a few speedboats of research.

In this section the author describes two related but remote examples where a speedboat, persistence over many years and attention to publicity and multiplier effects, has systematically shifted a tanked of practice. In particular it will focus on the multiplier effect of a professional development program for teachers and for trainers in which in-service work (when a trainer goes to the teachers' class and supports the teacher as he or she introduces new teaching methods with

their own pupils) plays a critical role. In Indonesia and in the UK we have been working with "inservice-onservice" models of professional development of teachers for nearly twenty years.

It proves to be a powerful model for effective professional development, since it overcomes the well-known problems of transferring skills learned in a professional development center to the actual classroom. There is, however a number of problems associated with the system. One is the cost of providing a trainer to giver personal support to each teacher in their schools, especially when schools are in remote locations (as is common in Indonesia), and another is the adequate preparation of trainers and the establishment of an effective method of coaching teachers which is neither 'inspectorial' nor simply a demonstration by the instructor of a teaching method.

The author describes more fully the form of the inservice-onservice model, and strategies for overcoming problems associated with it in Britain and in Indonesia, and also techniques for evaluating the effectiveness of the professional development in terms of improved by school students.

Canada

In this section the author focuses on the history of Science Education in Canada and the effect of language of instruction, local autonomy, religion, equalization of funding and accessibility, communication, vocationalism, and diversity on science teacher education; the effect of the TIMMS report on science teacher professional development and certification and the Pan Canadian protocol for collaboration on school curriculum informed by the vision for K-16 scientific literacy and the development of teacher education models to achieve this goal. The author examines the differences an dissimilarities in the way professional development is conducted in the provinces, the cultural and contextual factors involved in professional

development. He will share successes and alert others to the causes of failure during professional development of science teachers.

England

Shortly after coming to power, the Labor government set out a plan to train 'Advanced Skills teachers' who would have a 'key role to play in raising standards by supporting and mentoring trainee teachers and newly qualified teachers'. The UK Teacher Training Agency (TTA) has outlined five standards for subject leaders (that is to say, heads of department and primary teachers responsible for a subject) 'which set out the knowledge, understanding, skills and attributes' which 'define expertise in subject leadership and are designed to guide the professional development of teachers aiming to increase their effectiveness as subject leaders...' 'Key outcomes of subject leadership' include 'teachers who: work well together as a team; support the aims of the subject and are dedicated to improving standards of teaching and learning. The standards are difficult to make operational and unproved, particularly those relating to teacher development and should be regarded as, at best useful pointers for discussion, and at worst, as naïve and distracting state interventions. Mandatory appraisal for teachers was one strategy brought in recent years in order to make teachers observe each other and talk specifically about development. However, even its supporters in government recognized that appraisal has failed to gain universal approval in schools because it often fails to address teachers' needs adequately. The emphasis in appraisal has too often been the institution and not the individual. A second issue has been the inappropriate and inadequate nature of staff development available for teachers.

Science departments are often faced with a number of problems which are external to the school but which need to be understood by heads of departments. Firstly, school science is often

perceived as a whole by outsiders who are ignorant of the differing cultures, histories and traditions of the separate sciences and of the strains placed on science departments by the move to integrate science. Secondly, teachers with a limited knowledge of science often end up teaching science, particularly to younger students in secondary schools. Thirdly, the gender nature of science-physics has been seen as a 'masculine' subject – biology as 'feminine' – has often resulted in a gender imbalance in subject choices and in the gender mix of departments.

Germany

German scores in the middle of the field of all countries, which participated in TIMSS II and III. The fact that a country with one of the world's strongest economics is not among the upper group produced an intensive discussion about possible deficiencies within the educational system. Most comments on the TIMSS results point to a variety of reasons that could have caused this situation. For the elucidation of the main critical aspects, characteristic features of the German system of professional development in Science Education will be described and some problematic elements will be presented.

The most remarkable characteristic feature of the German system that is quite different from teacher training programs in other countries, is the great amount of subject studies students are obliged to do. Because of these demands many students need a lot of time for their studies. The average duration for physics students is 13 semesters (one semester =15 weeks). A critical point in all discussions about changes that are necessary, therefore, is the following question: What is an appropriate subject knowledge prospective teachers should have in order to be able to link this knowledge with pedagogical ideas on the one hand and to teach elementary topics in science from a high level of competence on the other? Another organizational peculiarity of the German system is the separation of a more theoretical phase of teacher education at the

university (including teaching practice for eight weeks, supervised by a professor of science education) and a practical phase (2 years) that takes place in schools exclusively and in which the prospective teachers are supervised by experienced teachers without any contact with the university. This separation gives the students the chance to get deep insights into both parts of the required knowledge but hinders them in connecting these parts in a sufficient way. These problems and other aspects of the German science teachers education programs will be presented in greater details.

Israel, Greece, Italy and the US

A major driving force in the current effort to reform science education is the conviction of many, that it is vital for our students to develop their higher-order cognitive skills (HOCS) capacity in order to effectively function in our modern, complex science and technology-based society. This means a fundamental shift from the traditional algorithmic teaching emphasizing knowledge acquisition, to HOCS-oriented learning, focusing on critical thinking. Such a paradigm shift means a different conceptualization, and, eventually, goals of the teaching-learning process which, in turn, requires different models of science teacher education with consequential results, effects and impact on the professional development of the prospective teachers as well as their professors involved in these programs. The HOCS-motivated reform in science education has had different expressions in different communities and contexts nationally and internationally concerning some emerging key issues and contextual factors. In view of the above, we have initiated and conducted within the unique science and mathematics teacher training program of our university, a longitudinal multidimensional collaborative national and (comparative) international study focusing on the following selected key issues, directly related to teachers' professional development and the quality of their teaching accordingly:

1) Assessment: Lower-order cognitive skills (LOCS) vs. HOCS – oriented exams and examination-type preferences of prospective teachers.

2) Critical Thinking: Disposition toward- and prospective teachers' capability of critical thinking (and of their prospective students).

All of these issues and related contextual factors (e.g. local culture, testing culture, teaching tradition, educational system, accepted social norms, and measure of success) will be thoroughly discussed in view of our collaborative corresponding research finding/results (in Israel, Greece, Italy, and the US). The conclusions of our studies and implications for the professional development of science teachers, their (science and mathematics teaching) and (their) prospective students' performance will be derived and summarized, in our proposed chapter, in terms of the current trends and reform in science education worldwide. Based on the above we will argue that scoring at the upper and lower ends of the TIMMS sample has, perhaps, something to do with those factors of science teachers' professional development associated with their HOCS-related dimensions which are so crucial for a successful LOCS-to-HOCS switch in science and mathematics education.

<u>China and U.S.</u>

This section presents:

- A close examination of the educational training and development of science teachers in China as compared to their counterparts in the U.S>, followed by a discussion of the pedagogical approach American and Chinese teachers employ in science teaching.
- Ways in which students respond to each type of instruction and how that effects the development of their cognitive skills. Throughout this paper, case studies conducted by both American and Chinese teachers who have undergone national observations of classroom

teachings will supply readers with a different perspective on the ways Chinese and American teachers view the two educational systems.

Furthermore, two senior elementary and high school science teachers who have taught for nearly twenty years under the Chinese education system will offer additional updates about the latest changes in its academic structure. Finally, the implication of thesis studies is discussed within the context of teaching and learning, and how the information gathered from both countries could be used to achieve different educational goals.

The Philippines

Recent publication of the TIMMS report has renewed interest in conducting research on international science teacher education practices. Historically, science education research has focused on evaluating the implementation of various science education curricular projects in international settings. Little, however, has been documented to understand contextual aspects of science education in these contexts, or to question underlying assumptions, which have framed research activities.

Historical Perspectives

In the proposed section, we would explore issues associated with conducting research in international contexts regarding professional development in science teacher education. The following is an outline of topics and themes, which are explored:

Efforts to research international approaches to the professional development of science teachers are showing shifts in terms of who and what is looked at in this field of research. In this section, the authors will present an historical review of international science education research on the professional development of science teachers. A look at the kinds of issues that have received attention as well as whom and how the research has been conducted will be reviewed.

For example, international research in the past has typically presented descriptions of enrollment numbers, programmatic structures, coursework or certification requirements, and curriculum implementation and evaluation reports. Until recently, much of the research was conducted using large-scale quantitative methods reflective of a positivistic research tradition. The historical summary will serve an important backdrop for discussion in a following section, which highlights research practices and assumptions, associated with current research.

Science Education Research in Today's Global Contexts

In this section, science educators from the US and Philippines pose several key questions regarding international research supported by examples from their experiences working abroad. One possible question to be explores is: How do we translate international research into culturally relevant practice? Possible issues subsumed in this category that we may want to examine are: internationalization of teacher education professional development curriculum; understanding dimensions of teacher and student learning (e.g. sociocultural, historical, personal, and epistemological influences). An example can be seen where researchers want to investigate the extent to which scientific literacy is promoted through science education in schools. In one country, scientific literacy is seen as critically important toward maintaining democracy; yet, in another apart of the world, scientific literacy represents a cultural threat to an indigenous population.

Implications for Developing Global Models for the Professional Development of Science Educators

Considering the dilemmas presented in the preceding sections, we explore a fundamental question in this section: What does it mean to develop global models for science teacher professional development? We suggest that the development of such models needs to center

around the negotiation of purposes served, and cultural issues associated with science education in the local setting. We will describe possible approaches for negotiating professional development and research activities with collaborating partners.

Trinidad and Tobago

This section critically examines efforts at the professional development of science teachers in the developing country of Trinidad and Tobago. It briefly outlines the mainstream professional development opportunities for teachers at the primary and secondary levels of the system. The contextual and other factors that have helped to keep this approach to the professional development of science teachers intact over decades are critically assessed. The author describes two innovations that were not mainstream activities but were initiated in an attempt to expose teachers more directly to some of the newer approaches to science teaching that were deemed to be relevant tot he local context. The primary science teacher initiative was mounted by a UN agency with financial support from other agencies. The main aim of this professional development program was to expose teachers to strategies for using the natural tropical environment to develop lesson plans and to teach several aspects of primary science. Emphasis was placed on integration across the curriculum. The secondary science teacher initiative was funded by a UN agency and was mounted by the School of Education. The overall goal of professional development was to expose the science teachers to the procedures for designing, producing, and using contextualized science-teaching materials. The specific strategy for producing contextualized materials was adapted from methods used by a foreign consultant (Lubben) and his co-workers in a similar situation in Swaziland (Lubben, Campbell & Dlamini, 1996). Science teachers are very enthusiastic about this model of professional development. They have devised additional objectives for the official curriculum document that they consider

to be essential if the science taught is to be relevant to the students' lives. They have included materials that they would not normally use in their teaching, but which they now realize are truly part of students' everyday experiences. For example, in the unit on water, they have included lessons on the reasons why some people do not receive tap water and the efficacy of a truck borne water supply system. In the unit on maintaining health, they have designed lessons on the impact of excessive noise from discotheque music and the music of the steel band (the national instrument) on one's hearing. The impact of this method of professional development of science teachers is being monitored as the lessons are piloted. One benefit that is obvious at this stage is that teachers have begun to open up their thinking with respect to making the science taught relevant to the local context. This section will provide further details of developing this professional development model and will highlight some of the issues involved in the education of science teachers in Trinidad and Tobago and discuss a new direction that holds some promise. The author will also discuss the contextual issues that arose during the introduction of a new model for professional development of science teachers. The section culminates with an exploration of the dynamics of introducing these two innovations, with some emphasis on successes and failure. Finally the author examines the level of continuity and the feasibility of making such programs available to a wider cross section of science teachers.

Large Urban, Multicultural, Multilingual US Communities

In this section, the author reflects on a university program for preparing American science teachers to teach in large, urban, multicultural, multilingual communities among students who often belong to cultures which are foreign to the teachers; the contextual setting in which the program was developed and taught, and lessons learned while teaching the courses in the program over a ten-year period. The program was designed to empower science teachers to cope

with the continuously evolving diversity in their classes while increasing interest and achievement in science. The overarching goal of the program was to increase the ability of teachers to create inclusive classrooms in which all students can learn science. Because of the success rate of the program it is now being used as a science teacher education model in another large urban school district. It is hoped that faculty at other teacher education institutions and teacher enhancement staff developers who are grappling with how to better sensitize teachers to issues of diversity while improving the teaching and learning of science and mathematics will find this useful. This section will describe the development of this model and provide answers to the following questions as the author reflects on her experience in science teacher education in the Caribbean, the US and with UNESCO.

Conclusion

This final section highlights the major lessons learned in the professional development of science teachers and will provide a summary analysis of what issues and perspectives arise during professional development for teachers of science in the global community. The author reflects on the differences and similarities in the way professional development is conducted in global communities; the contextual and cultural issues that arise, and the successes and inherent failures of some models.

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INFUSING TECHNOLOGY TO ENHANCE SCIENCE LESSONS: PROSPECTIVE TEACHERS AS ACTION RESEARCHERS LEARNING TO TEACH FOR CONCEPTUAL CHANGE

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High school students enter the science classroom having grown up in a technology-rich world of video games, personal computers, instant communication and Internet access. In writing about the potential of using technology in a constructivist classroom, Strommen (1995) points out that, since they are used to an environment outside of school where they control the flow and access of information, these students are naturally more interested and involved.

> Unfortunately, in many classrooms, knowledge is presented to students in a linear, didactic mode that differs dramatically from their previous experience outside the school. In contrast with the vivid images and self-directed flow of the interactive home and society, school strikes them as rigid, uninteresting, and ultimately alienating (Strommen, 1995).

With the ubiquitous presence of computers in schools, there are significant changes in the roles of the teachers using emerging technologies for instruction. The new professional teacher needs the skills to infuse technology into lesson plans in order to connect with technology-savvy children to improve their learning (Wise, 1997). Teaching prospective science teachers how to infuse their lessons with multimedia electronic technologies in a science education methods course may be a catalyst for changing the way science teachers teach high school students.

In this study at a large, public university in the southeastern United States, six prospective science teachers enrolled in a semester-long Advanced Topics in Teaching and Learning High School Science education methods course were challenged to become proficient using electronic technology to teach a science lesson. Concurrently, they practiced teaching science for conceptual change using sophisticated PowerPoint slideshows infused with video clips,

animations, and hyperlinks to Internet sites. Furthermore, they had the opportunity to practice teaching their science lesson in front of actual high school science students at the university's Developmental Research School (DRS).

While others have studied how teachers learn to use technology in the classroom (e.g., Means, 1994; Strommen, 1995) and teaching for conceptual change (e.g., Chiappetta, Koballa, & Collette, 1998; Posner, Strike, Hewson, & Gertzog, 1982), this study is unique in that I had a venue in which prospective teachers could practice teaching technology-enhanced science lessons to my own tenth grade biology honors class and a general chemistry class at the DRS. In addition to having extensive experience as a science teacher, I regularly infuse my science lessons with multimedia electronic technologies, and could demonstrate my own science lessons as well as provide my university students with continuous access to tenth and eleventh grade high school science students.

Purpose for the Study

The National Council for Accreditation of Teacher Education (NCATE) is promoting reform to ensure quality in the preparation of our nation's teachers with a vision of "the new professional teacher... know[ing] how to employ educational technology effectively" (NCATE, 2000). Few, if any, teacher education programs are currently meeting all of the National Educational Technology Standards for Teachers; few prospective teachers are developing the competence to use technology as a teaching tool (Wise, 1997). The International Society for Technology in Education (ISTE) released National Educational Technology Standards for Teachers which focus on preservice teacher education and define the fundamental concepts, knowledge, skills, and attitudes for applying technology in educational settings (ISTE, 1998). According to ISTE, all prospective teachers seeking professional certification should meet these

educational technology standards; ISTE further recommends that all teachers acquire competencies in basic use of computers and electronic technology for personal and professional uses as well as the application of technology for instruction.

Teacher education programs cannot predict how technology will change the teaching profession and college instructors cannot predict what knowledge, skills, and attitudes are essential for prospective teachers to perform successfully in technology-enriched K-12 classrooms. "Limited teacher training is often faulted for the low level of technology integration in the K-12 public school system" (Strudler, 1995). The majority of teacher education faculty does not model technology use to accomplish objectives in their courses, nor do they teach students how to use information technologies for instruction. For example, students are seldom asked to create lessons using technologies or practice teaching with technological tools (Strudler, 1995).

Research Questions

In studying the conceptual change in these prospective teachers and how they accommodated constructivist and reflective practices during this semester-long science methods course, I was interested in the following research questions:

- How do the prospective teachers' perceptions of using electronic multimedia technology to enhance their science lessons change throughout the semester?
- What evidence of conceptual change emerges for these prospective teachers during the semester as they revise and modify their PowerPoint slideshows?
- In what ways does instructor, peer, and high school science student feedback guide prospective teachers to modify science lessons?

It is important to note that this study explores the learning of two groups of students – the prospective teachers and the high school students at the DRS – and two categories of conceptual change – prospective teachers learning to teach science and learning to use multimedia electronic technology in the process. My primary focus was studying the prospective teachers in the science methods course.

Research Context

I had a dual role in this study as the course instructor for Advanced Topics in Teaching and Learning High School Science and as high school science teacher. The high school students who participated in this study were acclimated to seeing university students in their classrooms; prospective teachers from the College of Education intermittently observe, practice teach, and co-teach lessons at the DRS. When I told them that the prospective teachers would use PowerPoint slideshows accompanied by hands-on lab activities, my high school students were excited and enthusiastic, and promised to provide feedback about the multimedia and the lesson.

Although the prospective teachers who participated in this study had limited teaching experience and disparate competencies using computers and multimedia, all of them were science education majors, so I considered them to comprise a relatively homogeneous group. As they co-taught their science lessons with me in my classroom, I tried to minimize their concerns about student behavior and classroom management, the kinds of issues that student teachers have (Tabachnick & Zeichner, 1999).

Methodology

This study used naturalistic inquiry as the methodology (Lincoln & Guba, 1985). This allowed me to develop working hypotheses to interpret the instructional design of the prospective teachers' lessons and their pedagogy of the within the context of the methods course.

For this study, a variety of qualitative methods were used "to ensure truth value, applicability, consistency, and neutrality" (Erlandson, Harris, Skipper, & Allen, 1993): multiple observations, briefing and debriefing interviews, peer assessment, member checking, and a reflective journal.

I interviewed each of the six prospective teachers at the beginning of the semester to determine their conceptions of science teaching and learning and their educational philosophy. The survey of their educational philosophies included a short description for two classroom scenarios: Mr. Gates leading a class discussion in a traditional teaching style and Ms. Wagner leading a class discussion in a more constructivist teaching style. (adapted from Ravitz, Becker, and Wong, 1998.) After reading the descriptions, the prospective teachers were asked to associate their thinking with Mr. Gates or Ms. Wagner in regard to personal preference in leading a classroom discussion, the type of class discussion they believe that high school students prefer, and the type of classroom discussion in which they believe that students learn best. We discussed the results of this survey during a regular class meeting; each prospective teacher shared personal experiences to justify his or her response.

In addition to analyzing the survey and interview data, I evaluated the pretest and posttest questions that the prospective teachers constructed using quality criteria adapted from Chiappetta, et al (1998) to determine if the questions were traditional, closed-end or constructivist, open-ended. Finally, I analyzed the initial, tentative PowerPoint slideshows created by the prospective teachers for our first briefing interviews and compared them to the revised slideshows after presentation to the science methods class students, and the final version of the slideshow that was presented to the high school students at the DRS. I evaluated the structure and sequence of the slides using the quality criteria described by Krathwohl, Bloom, & Masia (1984): receiving, responding, valuing, organization, and characterization (pp. 172-184).

While science lessons are usually designed to give students information to promote conceptual change thinking, another component is often to change or establish attitudes (Martin, 1989).

I administered a pre-test to the high school students before the prospective teachers taught their technology-enhanced lessons in my science classes. The posttests were administered at the end of the science lesson to determine if conceptual change had occurred for any high school students. In addition, I solicited immediate verbal and written feedback from the high school students about the quality and impact of the PowerPoint slideshow used during the lesson. Prospective teachers met with me before teaching the science lesson to their university classmates in the methods course. We met again after the lesson to debrief and discuss the peer comments and my observations in order to determine the appropriate revisions and modifications for improving the PowerPoint presentation. I suggested using alternative sequences of slides, and commented on the selection of images and more animation based upon my personal experiences as a science teacher. I also encouraged them to describe their feelings about the process of revision and record any difficulties or frustrations they were experiencing in their reflective journals. In order to put the prospective teacher 's slideshow in real context, I asked, Did you do what you said you would do? Was your slideshow more than just entertainment? Did you follow the guidelines of the 5-E model? The reflective journal for each prospective teacher also served as a research notebook. They regularly wrote about the progress of own action research project – their questions and interpretations of the data they collected from their peers and the high school students, their reasoning and rationale for changing their PowerPoint slideshows, and difficulties they were having.

After each prospective teacher taught a revised lesson at the DRS, we met to discuss the high school students' feedback, my observations, and their self-reflections. At this point of the

semester, I used a regular class meeting to engage them in the analysis of data they had collected for their action research projects. Finally, at the end of the semester, I conducted an exit interview with each prospective teacher to discuss the reflection journals and action research projects.

We met as a class for ninety minutes twice each week. During our class meetings, the prospective teachers reconstructed their memories of their high school science classes as we discussed group work, "cookbook" science labs, drill-and-practice seatwork, instructional videos, teacher demonstrations, computer simulations, using probeware for data collection, developing a rationale for teaching Science, Technology and Society units; and engaging students in science fair research projects. In addition, we examined what they learned in previous methods classes and during their previous classroom observations of experienced science teachers. As appropriate, I regularly shared actual stories about my own science classes for analysis and discussion.

The Prospective Teachers' Action Research Questions

In integral component of this science methods course is engaging the prospective science teachers their own action research studies. During a science methods class, early in the semester, we discussed how to do action research (Dick, 1997). I guided them as a group to devise and refine their own research questions to explore their own teaching and learning about the effective use of electronic technologies in the secondary classroom. Their research questions included

- How do I use multimedia effectively to motivate students to pay attention during a science lesson?
- How does an animation or video clip help science students correct their misconceptions about natural phenomena?

- In what ways do girls and boys respond to PowerPoint slideshows and multimedia when I am teaching a science lesson?
- What difference does a complex PowerPoint slideshow make for high school students to learn science concepts?*(sic)*
- What kinds of "bells-and-whistles" must be included in a PowerPoint slideshow to get high school students engaged during my science lesson?

To illustrate how different assumptions lead to fundamentally different conceptions of the use of technology for teaching science lessons, this paper provides a new perspective toward teaching prospective teachers how to infuse their science lessons with electronic technology. This paper also describes how some prospective teachers think about how science students learning and how those beliefs influence their lesson planning. In each case, the prospective teacher's pedagogical philosophy becomes the guiding focus of this study.

Data and Observations

Results of the Survey Questions at the Beginning of the Study

- *Which type of class discussion are you more comfortable having in class*? All of the prospective teachers believed that they could successfully lead a class discussion like Ms. Wagner's. Most of them described a high school class taught by a teacher whom they considered exemplary and constructivist.
- *Which type of discussion do you think most students prefer to have?* Abygail and Tiffany believe that students prefer more traditional discussions like Mr. Gates'. Samantha, Christina, and Mike chose the type of discussion that Ms. Wagner was leading because they believe that teachers should be flexible even when the class is off the original topic. Jimmy explained that he chose undecided because he has no teaching experience.

- *From which type of class discussion do you think students learn more science?* Jimmy and Christina could not decide, ostensibly because they have no teaching experience. Their classmates believe that students learn more in a constructivist classroom like Ms. Wagner's but they could not justify their answers.

These data are tentatively analyzed as resulting from naïve assumptions about science teaching and learning as well as from a lack of familiarity with the tenets of constructivism (Bybee, 1997). Although these students had previously taken a methods class in which constructivism was modeled and promoted, perhaps these students have had few previous experiences in a constructivist science classroom during their secondary schooling and college classes. There was insufficient data collected in this study to explore this further; however, it provides a reference point from which to determine if any conceptual change has occurred during the semester-long course.

According to Posner, et al (1982), conceptual change occurs when students become dissatisfied with their present ideas or beliefs about a phenomenon they have observed, when they accept evidence that another explanation makes more sense, and when they believe that this new explanation is useful in order to learn more about the concept or idea. These prospective teachers were unfamiliar with this conceptual change terminology. Jimmy wrote in his journal:

> I began to get a little worried. I was not just teaching students some cake lesson out of a book, but I was actually gonna have to change some preconceived ideas that students might have. Learning that I would be using conceptual change as a technique changed my thought process completely. I would have to actually put some thought into this. . . .my ideas about teaching the lesson had changed. . . .(Excerpted from Jimmy's journal, beginning of semester.)

<u>Analysis of the PowerPoint Slideshows</u>

Krathwohl, et al (1984) suggest that instructional designers must address student needs in the affective domain as well as the cognitive domain. When the prospective teachers analyzed

their PowerPoint slideshows during our first briefing interview, each slide was inspected to determine its value for engagement, exploration, explanation, elaboration, and evaluation. All of the prospective teachers indicated that they wanted to find better images, animations, and video clips. Most of them decided to delete some slides that did not provoke inquiry and many of them rearranged their lessons and changed the order of their slides. Jimmy wrote about his thinking:

> After I learned that I had to focus on the concept, my PowerPoint outline changed. Instead of listing the definitions we would be going over, I set it up in a way that the students would have to answer the questions I asked, and then a slide would come up clarifying what they had just answered. This made my lesson more of an inquiry lesson. Before it was just straightforward. (Excerpted from Jimmy's journal, mid-semester.)

After each prospective teacher presented a mini-lesson to the science methods class, the audience of peers was asked for a written assessment of the slideshow and we discussed the lesson as a group. After class, each presenter met with me to debrief the lesson and consider the peer comments. Some of them were sheepish about their "performance; however, all of them valued the feedback and decided to revise their slideshows. Although she did not admit this during our debriefing, Kristy wrote in her journal that she had carefully designed her lesson to impress her classmates and now had to revise it for the high school students:

> I wanted to look so good . . .. I think I didn't want anyone to say that teaching was not something I could do well. It has already become such a part of my personal identity. The [high school] students were not the people who I wanted to please; it was those others who want the same dream. (Excerpted from Kristy's journal, mid-semester.)

<u>Constructive Criticism from the Peer Assessments</u>

The peer critiques about the PowerPoint slideshows were forthright, pragmatic, and constructive. Comments included: rearrange the order of slides, emphasize the importance of a video clip or animation, select larger graphics, change font size and colors, incorporate text builds and slide transitions to maintain instructional momentum and sustain student interest.

The prospective teachers made final revisions to their slideshows and constructed a pre-test before presenting their lessons to my high school science students–they were confident that their slideshows would engage the students in inquiry. All of the prospective teachers in this study anticipated that their PowerPoint slideshow would stimulate higher level thinking by the high school students, pique their interest in the topic, and create disequilibrium in their thinking

<u>Constructive Comments from the High School Students</u>

In the high school science classroom, four of the prospective teachers discovered that most of the twenty-nine students in the class were anxious to engage in the lab activity that accompanied their PowerPoint presentation. Two of the prospective teachers were disappointed that the high school students were not more responsive during the slideshow portion of the science lesson, although the results of the post-test indicated that the students had learned the concept the were teaching. When the prospective teachers conducted a review at the end of their lessons, most of them were delighted that the high school students could answer questions about what they had learned. Some of the high school students admitted that they misunderstood the concept of surface tension and density, and had changed their minds after seeing the PowerPoint examples and doing the lab activity. When the prospective teachers analyzed the pretests and posttests, they confirmed that most of the high school students answered the posttest questions that required higher level thinking correctly.

When the prospective teachers and I debriefed after their lessons and evaluated the students' comments in view of the effectiveness of their PowerPoint slideshows, we considered the impact of the video clip, whether the sequence of slides was logical, and the effectiveness of the images, animations, and hyperlinks. Not only did these prospective science teachers receive input from their instructor and their peers in the science methods class, there was a target

audience of high school stakeholders with the savvy to provide an additional perspective regarding effective use of technology when teaching a science lesson.

Many of the high school students wrote that the video clip was entertaining and helped them learn the concept; several were uninterested in the images, they only wanted notes for the posttest. Suggestions to improve the slideshow included adding graphics, using custom animations, changing layouts or colors. A few recommended additional movies and sounds so that the slideshow wasn't so boring. All of the prospective teachers believed that the comments were valuable. One of them wrote in his journal:

> The lesson went well: the video I [showed] of the astronaut on the moon seemed effective, but upon receipt of the feedback, the class was bored by it.... The aim was too low, and most of the class hated wasting their time. Fixing this lesson would mostly consist of me better using the PowerPoint. I used graphics only to illustrate a point. Instead, I could have used the pictures to set up an example, which is something I never thought of until after the presentation. (Excerpted from Mike 's journal, end of semester.)

<u>Results of the Survey Questions at the End of the Study</u>

During the exit interviews at the end of the semester, I queried each prospective teacher with the same questions about discussions in Mr. Gates' and Ms. Wagner's classes to determine if their beliefs about the roles of teachers and students in science classes had changed. Each of them had experienced the role of a teacher leading a class discussion in an actual science classroom and I wanted to know if they viewed constructivist practices differently now. I was looking for evidence of conceptual change in their thinking. As we discussed epistemology and pedagogy, some of the prospective teachers stated that they believed a constructivist approach to teaching science should result in increased student learning. The vignettes and results of the beginning and ending surveys are found below and in Table 1.

Mr. Gates was teaching his biology class in an animated way, asking simple questions that the students could answer quickly based on the demonstration they had seen the day before

and the homework reading assignment. After this review, Mr. Gates presented the class pre-lab material, again using simple questions to keep students attentive and listening to what she said.

Ms. Wagner' class was also having a discussion related to the demonstration and homework reading assignment, but many of the questions came from the students instead of the teacher. Though Ms. Wagner would clarify students' questions and suggest where they could find relevant information, she didn't really answer most of the questions herself.

Table 1

Comparison of Beginning of Semester Survey and Exit Interview

	Definitely Mr. Gates'	Tend towards Ms. Gates'	Can't decide	Tend towards Ms. Wagner's	Definitely Ms. Wagner's
BEGINNING OF SEMESTER					
a. *Which type of class discussion are you more comfortable having in class?*				A, S, J, R, C, M	
EXIT INTERVIEW					
a. *Which type of class discussion are you more comfortable having in class?*					C, S, J, M
BEGINNING OF SEMESTER					
b. *Which type of discussion do you think most students prefer to have?*	A, R	J		S, C	M
EXIT INTERVIEW					
b. *Which type of discussion do you think most students prefer to have?*	A	R		C	J, S, M
BEGINNING OF SEMESTER					
c. *From which type of class discussion do you think students learn more science?*			J, C	R, S	A, M
EXIT INTERVIEW					
c. *From which type of class discussion do you think students learn more science?*	A	R		C	J, S, M

A=Abygail, S=Samantha, J=Jimmy, R=Kristy, C=Christina, M=Mike

Although they carefully followed the 5-E model to construct a PowerPoint slideshow to teach a science lesson for conceptual change, Abygail and Rebecca had not completely changed their conception of teaching and learning–their responses to the first question indicate that they

are more comfortable leading a traditional discussion than a constructivist classroom. Both of them indicated that they also believe students prefer the traditional classroom discussion and will learn more in this setting. Abygail explained in her journal:

> I really wasn't aware that on the average high school students are very basic. They need things pointed out to them. They need to be told exactly what to do. Now, either I was a very bright, independent student in high school or I don't remember being that elementary. (Excerpted from Abygail's journal, end of semester.)

Abygail did not receive as many positive comments from the high school student about her PowerPoint slideshow and science lesson that her classmates did. Perhaps Abygail's response to the question was defensive because she felt she had no "real" control of the class; or, perhaps she simply reverted to teaching the way she was taught. She was concerned about students who were not paying attention to her. She chided them, "Hey! Pay attention to me" and "You have to write this down if you want to pass the posttest, so quit talking." Abygail wrote about this situation in her journal:

> On the left side of me there were a couple of students that were not paying attention at all or just plain non-participatory. I had a hard time dealing with [them] because it was not my classroom officially. (Excerpted from Abygail's journal, end of semester.)

At the beginning of the semester, Jimmy was undecided about how science students think and learn. He asked if the PowerPoint was supposed to be entertaining to capture the students' interest. When I reminded him about his question at the end of the semester, he stated that, now that he was more familiar with constructivist teaching and learning, he knew that the PowerPoint was supposed to be much more than entertainment, "but it could engage the student if it was interesting enough."

Samantha, Jimmy, Mike, and Christina indicated that they would be comfortable in a discussion like Ms. Wagner's, but I am not certain that all four of them have a clear and deep

understanding of the roles of the teacher and students in a constructivist classroom after interviewing them and reading their journals. Samantha wrote:

> I liked being the "teacher" and knowing that students look up to me for answers and direction. I think having experience teaching baton twirling, and knowing how to take an authoritative role, gave me the confidence to be the one in charge. I never really was to hesitant about being in front of the class, I just didn't want to make a mistake, or not know enough information. (Excerpted from Samantha's journal, end of semester.)

Results of the Action Research Projects

The action research projects seemed to help these prospective teachers to identify and reflect on their underlying assumptions about what science teaching and learning is and the potential for using electronic technologies to enhance their lessons. I did not require a formal report oat the end of the semester because I was more concerned that they would spend more time in and out of the science methods classroom to reflect on their experiences in the DRS science classroom. Their journals indicate that they were learning to engage in reflective practice. Below are some comments from the their journals:

> It's different to try to read and understand what it is like to teach, but to actually do it is so much more beneficial. You can find your flaws, and fix them. I went into this class feeling a little overwhelmed, but I left feeling more confident and assured of teaching. I did not realize how much technology can enhance teaching. (Excerpted from Samantha's journal, end of semester.)

> This class not only taught me the technology that goes along with teaching but also gave me confidence in my ability to teach with technology. (Excerpted from Jimmy's journal, end of semester.)

> This class actually made me feel like a teacher. For the first time in my college career, I was thinking like a teacher. Now when I make lessons or look at web sites, I ask myself how they would be valuable to my students and me. (Excerpted from Abygail's journal, end of semester.)

> Even though I only taught one lesson, I learned so much about how to think, what my students are thinking. . . . I wish there were more courses like this one throughout the education program, because it really opens your eyes to the real world of teaching, and not just hearing about it from a professor who hasn't been in a high school classroom for twenty years. (Excerpted from Christina's journal, end of semester.)

Discussion

Calderhead (1983) suggested that prospective teachers have no schemata for pace, level of intellectuality, affect, and work orientation of high school students since they lack the complex knowledge that experienced teachers have. During the science lessons, I recognized a myriad of student behaviors which indicated that student learning was taking place– eye contact, note-taking, courtesy, enthusiasm, verbal responses to teacher questions, and engagement in the lab activity. Although most of the prospective teachers asked questions at the beginning of their lessons to discover the high school students' prior knowledge about the topic, only a few were able to use their knowledge of their students' thinking to plan their teaching. When we discussed the feedback from the high school students during the science class, each prospective teacher explored his or her own action research questions, asking, Do these DRS students simply "know the drill," answering teacher questions dutifully and following the visuals on the slideshow passively? Did any students other than visually oriented students benefit from this lesson? Were the students only marginally interested in the video clips and animations?

During my debriefing interviews with the prospective teachers, I tried to describe what kinds of learning I understood to be going on in the classroom and why the high school students did not respond to the PowerPoint slideshow with much enthusiasm. A colleague of mine at the DRS added this explanation for the comments by the high school students:

> These high school students are not all-visual learners–they may need to hear it, may need to do it, or touch it– but they all seem to be *oriented* to visual stimuli. They have been acculturated by television and video games; they are a video generation. They are savvy [as an audience]when it comes to PowerPoint because they know how to construct them and they sniff at inferior work. [W]hen you cross over to using PowerPoint for a lesson, it had *better* be more than a high tech blackboard. Want credibility with students? If you cannot do it [PowerPoint] well, do not bother doing it at all. (Mrs. Walters, English teacher, personal communication, end of semester, italics added.)

What is unique about this study? Since I was the science education methods instructor and I also teach at the DRS, (1) I linked a science methods course and a "real" science class for the prospective teachers, (2) I was able to enlist a group of actual high school science students to comment on each prospective teacher's lessons, (3) as the regular science teacher, I knew which of the high school students would provide useful comments and could screen out the less useful responses from those students who were uninterested in participating in the study. Although most of the twenty-nine science students in the DRS classroom comprised a pool of interested and experienced informants, capable of articulating their comments, statements that were clearly counterproductive were discarded (e.g., "it [the slideshow] was really pathetic.")

The prospective science teachers in this science course critiqued and evaluated each other's lessons to determine if they followed the steps for conceptual change. They began to recognize how student experience and expectations about electronic technology affects lesson planning and demonstrated some conceptual change in their pedagogical views. All of the prospective teachers constructed their PowerPoint slideshows using the 5-E teaching model. When they revised the slideshow, they systematically searched for the more effective visuals and redesigned slides to engage the high school students in higher level thinking instead of utilizing the slideshow as a sophisticated overhead projector to provide definitions and information for note-taking. Even the pre- and posttest questions were carefully constructed to provide the evidence they needed to determine if the students had changed their conception because of the lesson.

As the instructor of this methods course, I guided the prospective teachers as they made many of the revisions. I continually challenged them to reflect on their thinking about how students learn and how they would learn to teach science. Perhaps total conceptual change is too

great an expectation within the limited time apportioned to methods classes (Gess-Newsome, 1999a). Prospective teachers need to become aware of their own implicit conceptions about teaching and learning science in regard to the understandings and actions in teaching – they teach the way they themselves learn best.

The prospective teachers in this study initially believed that teaching is telling and learning is gathering information. Years of apprenticeship of observation and of watching the public behaviors of teaching have led them to believe that they understand what is required of teaching (Lortie, 1975). Their first PowerPoint slideshows were mostly definitions and information. Teacher educators, on the other hand, may view teaching and learning quite differently: "Four time-honored conceptions of teaching are recognized: teaching as cultural transmission, skills training, fostering natural development, and promoting conceptual change" (Scardamalia & Bereiter, 1989). If methods instructors can help prospective teachers identify the appropriate points for integrating technology into their pedagogical practice, there is a greater potential to support deeper, more reflective, self-directed student learning.

Recommendations

Since technological advancements are affecting the way we teach and learn in high school science classrooms, teacher education programs for must integrate technology early in the sequence of courses leading to professional certification for science teachers. Furthermore, science education methods instructors must model how to use electronic technologies in the teaching and learning process if prospective teachers are to adopt a fearless attitude in the use of technology. "The idea is not only to teach them how to use the hardware and software, but how to integrate it seamlessly into the curriculum. Otherwise, it doesn't work..." (Siegel, 1994). Science education methods instructors must provide authentic opportunities for prospective

science teachers to practice teaching technology-enhanced lessons long before the semester traditionally scheduled for a classroom internship. To be most effective, these pre-internship experiences should take place in a public school setting which includes the target audience of high school students, and the prospective teachers should be engaged in their own reflective studies. One of the prospective teachers in this study wrote that he was able to concentrate on his lesson in my classroom despite my presence:

> I was never intimidated by his [the teacher's] presence in the classroom. It made me a little bit more confident knowing that he was there to help me in case I needed it. I knew that I was the one teaching the lesson, so it was strictly up to me to get my points across to the class. (Excerpted from Samantha's journal, end of semester. Pseudonyms are used throughout this paper.)

The journals of the prospective teachers in this study seem to indicate that my extensive experience as a science teacher, my familiarity using electronic technologies for teaching science lessons, the availability of my secondary science classroom for practice teaching, and easy access to student feedback appear to have benefited them during this science methods course. One of the prospective teachers wrote that these classes helped her start thinking like a teacher:

> It was very helpful to have an experienced teacher there to ask me open-ended questions that got me thinking. I finally have to think like a teacher and his questions allow me to do that. (Excerpted from Christina's journal, mid-semester.)

As educational researchers explore collaborative relationships between science education methods instructors and local high school science teachers, I hope that more evidence will indicate that practice teaching in a "real" science classroom full of "real" high school science students provides more realistic experiences for prospective teachers than the methods course classroom on a college campus. When technologically-savvy students and experienced teachers team up in the tutelage of prospective science teachers, there is potential for equipping new teachers with the skills requisite for successful and rewarding careers.

Many students in our high school classrooms have multidimensional experience with interactive media outside of the school and they may be more techno-literate than their science teachers. The prospective teachers in this study learned about infusing technology to teach science lessons for conceptual change. Some of them showed signs of their own conceptual change toward teaching and learning science as evidenced by their deliberate, iterative modifications to their PowerPoint slideshows–they wanted to impact student learning and believed that a technology-enhanced tool would be effective. Although they demonstrated a limited understanding of the 5-E model of teaching for conceptual change, the prospective teachers were enthusiastic about their teaching experience in the high school classroom. College students in methods calsses such as this one may need to undergo conceptual change with respect to their notions of teaching, learning, the nature of science, and/or the nature of knowledge (Gunstone & Northfield, 1992). As he planned his lesson, one of the prospective teachers wrote in his journal:

> I realized that just learning a bunch of terms is not conceptual change. I switched my mode of thinking to a broader concept. I was asked the question, What is the one thing that you want the students to leave there knowing? This made me realize that terms and definitions are great, but do students actually learn? If there is no main concept to go along with the terms and definitions, then what good are they? (Excerpted from Jimmy's journal, beginning of semester.)

In spite of the fact that the short duration of the study limited the impact of their action research, it appears that these prospective teachers also learned new reflective skills. The interview data and reflective journals indicate that the authentic classroom experience enhanced this constructivist-based science methods course; they also suggest that constructivist-based instruction, which includes the use of multimedia, helped these prospective science teachers develop positive attitudes toward computer-related technologies. Future researchers may examine parts of this instruction model in detail to identify specific items or procedures that

contribute to enhancement of prospective teacher education. Thus, the significance of the study has practical and theoretical implications for teaching secondary science methods courses based on a constructivist approach.

Limitations of the Study

There are a number of issues that emerged during the data collection, analysis, write-up, a and presentation of this study. Some of the issues are related to my expectations as a methods course instructor during the short duration of the study– my expectation that these prospective teachers could concurrently learn about how to teach an inquiry lesson for conceptual change and learn how to conduct their action research projects. Another issue arose regarding the data sources, such as whether the peer assessments and high school student comments are credible and unbiased. I also must speculate – what effect did my own educational philosophy, pedagogy, and epistemology have on the participants? Were they constrained to construct and teach lessons using my teaching style? How did my presence in the classroom, ostensibly to manage student behavior, impact their student teaching? Two of the prospective teachers were preoccupied with my presence, one wrote that she would have corrected two of my high school students who were talking during her lesson, but she did not want to usurp my authority. The other was concerned that I was judging her performance and claimed it distracted her. If these issues affected the teaching of the lesson, it may have affected the high school students' assessments and feedback.

One of the prospective teachers wrote that she wanted to impress her classmates when she taught her practice lesson in the methods classroom. I do not know if she will invest as much time preparing inquiry lessons and infusing technology during her student teaching. I was startled that she was less concerned with impressing me or the high school students and I suspect that she had less conceptual change throughout the semester compared to the other methods class

students. Perhaps she regressed to a more traditional model of teaching because it was more familiar. She described herself in class as successful "and more comfortable" during high school and college taking traditional courses. She was somewhat skeptical that students will benefit in a constructivist classroom. Hence, I am not sure how to get at her thinking without additional interviews. I do not know if she is receptive she did not provide rich data in her journal.

Since this study lasted only one semester, there did not appear to be sufficient time for conceptual change to occur in the prospective teachers. Furthermore, they only visited my high school classroom once or twice–three of them indicated in their journals that they wanted more practice time in the "real" classroom. I encouraged them to use the 5–E learning cycle steps; however, two of them told me during the exit interview that they could not change the lesson "on-the-fly" after finding out what prior knowledge the high school students had. I told them I believe that experienced teachers have a tacit understanding of classroom dynamics that comes with practice. Four of the prospective teachers wrote that, after teaching the lesson, they understood why I emphasized building rapport with high school students and why I espoused designing lessons that address the affective domain.

Perhaps I attempted to cover too much in one semester: learning to use new electronic technologies, exploring curriculum materials and embracing too many new concepts about how to teach science in a secondary classroom. Learning to teach inquiry lessons is difficult enough, I directed these prospective teachers to teach inquiry science lessons for conceptual change. Jimmy's journal entry describe the conundrum for him until he realized that this teaching strategy goes way beyond giving definitions and talking about a phenomenon. The action research was new to all of the students in this methods course, but at least one of them, Abygail, wants to continue the journaling and self reflection when she student teaches.

During the semester, I modeled teaching behaviors to the methods class that I consider to be effective; however, I emphasized that each of them would need years of practice planning lessons, teaching "real" students, assessing their learning, and reflecting on the outcome. Perhaps participating in the study will begin the process for them. A follow-up study of their student teaching experiences might indicate that some of the course objectives in this methods course were reached and embraced by these prospective teachers. I hope these prospective teachers evolve into reflective science teachers who regularly infuse their inquiry lessons with multimedia in a determined effort to teach for conceptual change.

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PROFESSIONAL DEVELOPMENT FOR ELEMENTARY SCHOOL TEACHERS WORKING WITH SCIENCE LEARNING OUTCOMES

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Queensland, like other states in Australia, has moved toward the introduction of a new grades 1 to 10 science curriculum (Queensland School Curriculum Council [QSCC], 1999a). This was based on *A Statement on Science for Australian Schools* (Curriculum Corporation, 1994), which was developed after the various states agreed to have a common basis for curriculum development in eight areas of learning, including science. The curriculum was published as a syllabus, which in this context means a mandated curriculum framework. A number of support documents were also published. After two years of development and trials, the new science syllabus was distributed to schools in July 1999, for implementation over the following three years. Like most contemporary syllabuses and mandated curricula the new science syllabus is organised as a series of learning outcomes presented in a continuum across several levels. In the Queensland syllabus, there are six levels across the ten years of compulsory schooling. Outcomes describe what children will know (understanding) and can do (working scientifically) at each level. The science syllabus is one of the first of the outcomes oriented syllabuses to be introduced in the state, and presents a considerable challenge to teachers because it is very different from the content based syllabuses they have been used to. Further, it is strongly constructivist (McInerney & McInerney, 1998) in its orientation; a view of learning and teaching which remains new to many teachers. The differences in the new syllabus make the move to implementing it rather daunting and challenging for teachers, especially for those not specialising in science such as elementary school teachers[1]

Context and Background

The teaching of science in Queensland elementary schools has for many years been variable. While a number of teachers teach it regularly, there is a high proportion of teachers who tend to teach science occasionally, if at all (personal communication – an unpublished survey of science teaching practices was conducted during the syllabus preparation). The picture has therefore not changed a lot since a similar pattern was identified by Varley (1975), despite what was considered by many to be a highly successful syllabus (Queensland Department of Education, 1981a) and support material (Queensland Department of Education, 1981b). Such a pattern of elementary science teaching is not uncommon in other Australian states (Australian Science Technology and Engineering Council, 1997), and indeed in other countries (Gustafson & Rowell, 1995; Harlen, 1997). However, a positive outcome from the 1981 syllabus was that teachers who taught science tended to be more willing to use hands on activities; though there also was considerable variation in what the teachers saw as hands on (personal communication – an unpublished review of public school operations was conducted in 1999).

The difficulties that many elementary school teachers experience in teaching science have largely been attributed to the limited amount of study in science undertaken by elementary teachers (Australian Science Technology and Engineering Council, 1997; Department of Employment, Education and Training, 1989). This leads to many teachers having low levels of confidence to teach science (Abell & Roth, 1992; Appleton, 1995), and limited pedagogical content knowledge (Shulman, 1987) in science (Appleton & Kindt, 1999; Osborne & Simon, 1996); an essential component to effective science teaching (Veal & MaKinster, 1999). While other factors such as resource availability and class management

(Appleton & Kindt, 1997; Varley, 1975) may also contribute to teachers' difficulties in teaching science, the above reasons remain foremost in the literature. Given this context, for many elementary school teachers, the implementation of the new science syllabus presents an insurmountable problem. Many would simply not try to implement the new syllabus, or make only a token attempt to do so.

Relation to Other Work

Appropriate professional development for elementary school teachers is one way of helping some teachers past this barrier so that they could potentially begin to transform their teaching of science. Previous professional development efforts in Queensland have been shown to be relatively ineffective (Anderson, 2000). In this study we therefore conducted a pilot study exploring the type of professional development which would be transformative for teachers trying to work with the new syllabus (Bell & Gilbert, 1996), but feasible within a large education system. In the past in Queensland, professional development associated with the introduction of a new syllabus has tended to be "top down", where the developers identify the new knowledge and skills that teachers need to implement the syllabus, and these are delivered to teachers in whatever format can be afforded by the education system. Partly because of cost considerations, such professional development has touched only a limited number of teachers, who typically may receive a few hours – or at best a few days – of professional development. Implementation of new syllabus has consequently not been very effective.

Regarding professional development for the new Queensland syllabus, elementary school teachers would need to understand its key elements of outcomes, constructivism, and working scientifically. From the literature, we also expect that they would need support in

science content knowledge, science pedagogical content knowledge, and perhaps aspects of resourcing and management. Earlier studies (Appleton & Kindt, 1999; Appleton & Doig, 1999) arrived at the notion that some elementary school teachers use "activities that work" as a substitute for pedagogical content knowledge in science. Suitable activities also provide some science content background knowledge, as well as resource and management ideas (Osborne & Simon, 1996). However, the practice of using isolated activities as the basis for a science program was shown to have difficulties in terms of students' cognitive achievement and the use of constructivist-based teaching strategies advocated in the new science syllabus material; therefore the notion of "units that work" was proposed (Appleton & Doig, 1999). This study was therefore built on the premise that an outcome of the professional development should be science units that work for elementary school teachers. What we did not know was how the necessary professional development pieces would fit together to generate this outcome, or even whether this was achievable within the envisaged professional development framework.

The Study

In discussions with representatives from a local Catholic Education Office, we identified the need to provide for teachers, effective professional development in implementing the new science syllabus. Our research purpose was to identify the professional development needs of teachers in implementing the new science syllabus, with a view to developing a model or set of principles which might guide the Catholic system in its provision of support for schools. The initial pilot study which emerged from this research agenda had both a secondary school and a elementary school focus. This paper reports on the

pilot study in an elementary school. The results of a pilot study in a secondary school have been reported by (Harrison & Appleton, 2000).

Methodology

The school which participated in the study was nominated by the Catholic Education Office (CEO). Two years earlier the school had trialed a draft of the new science syllabus. In discussion with the school principal and the CEO curriculum adviser, we decided that the pilot should involve a focus group of three teachers who had been involved in the draft syllabus trials, and were therefore familiar with the syllabus. The focus of the pilot study was on these teachers' cooperative planning of a science unit of work based on the new syllabus. From such an activity, we expected that the professional development needs of the teachers in planning a unit of work would emerge, and the teachers would conclude with a unit plan that they could use in their classroom.

We felt that the teachers would be best placed to tell us what their needs were, hence saw them as participant researchers. In the project, we jointly constructed a professional development plan derived from their existing beliefs and knowledge, their professional experience, and their experience in the planning exercise; and from my (KA) perceptions of their expressed and implicit needs identified from the planning exercise and our extensive professional experience.

The study therefore consisted of a case study of a focus group of teachers involved in a planning exercise. As is appropriate for such studies, we sought a rich data set in order to provide a thick description of the planning episodes (Merriam, 1998). This then provides a basis for the reader to determine the credibility and trustworthiness of the study findings (Guba & Lincoln, 1989).

The Participating School and Teachers

The participating school was located in a regional town within the local Diocese of the CEO. It was a larger school than normally experienced in the Catholic system, with about 430 pupils. The pupils were drawn largely from working and middle class Caucasian families, and were placed in mixed gender classes.

The three teachers who had been suggested by the principal had been teaching for more than fifteen years, and one, Robyn, had had recent experience in the United Kingdom. Peter was enthusiastic about science, and Sarah was a curriculum consultant in science within the school. The children in the teachers' classes were from grades 4 to 7 (aged approximately 9 to 12 years). All of the teachers had consistently taught science for many years, and were fairly confident about teaching it, even though none of them had specific science qualifications. All of the teachers had been involved in the earlier syllabus trial and were familiar with its constructivist basis, its notion of working scientifically, and had an appreciation of the learning outcome framework. That is, we were starting with an unusual subset of the elementary school teacher population, since these teachers might be considered as "high flyers" with respect to science teaching. We saw this as a logical place to start our pilot study as such teachers could more readily reflect on their own needs and professional development, and would not be reluctant to share their ideas.

Data Collection and Analysis

Three planning meetings of about two hours each were held with the teachers. They were attended by two researchers, (KA and an assistant, Margaret Rogers) and a Catholic Education Office curriculum consultant. The teachers were asked to cooperatively plan a unit of work based on nominated outcomes from the syllabus in the content area of "the Water

Cycle" for a grade 7 class. As a school plan had not yet been developed[2], the planning activity simulated the information that a school plan would provide for teachers. The activity helped set the scene for the group meetings so the teachers could quickly move to unit and lesson planning. Our choice of the content was deliberate, in that we knew that resources would be available, and that it drew upon science content with which elementary school teachers traditionally are not confident. Our role during the group meetings was defined as observers, facilitators and helpers, with these roles being assumed as the need arose.

The meetings were audiotaped, and field notes recorded. Unfortunately, during the first meeting the cassette recorder malfunctioned, and nothing was recorded, so we had to rely on our field notes and reflections recorded immediately after the meeting. Later the audiotapes were transcribed, and key statements and comments from the field notes identified. These were used to track the procedures used by the teachers in developing their unit plan. Inferences about professional development needs were drawn from these procedures and useful statements identified. These insights were fed back into the next meeting at an appropriate time for consideration by the teachers. The final session concluded with a discussion about the format and content of a professional development program which might suit a wider group of teachers who were less familiar with the syllabus and felt less confident about teaching science.

The first author and primary researcher in this case study has worked in elementary science teacher education for 25 years, and before that taught in elementary schools. His personal approach to teaching and research is derived from a constructivist framework, which developed initially from a Piagetian view but has more recently moved toward social constructivist ideas (Appleton, 1997; McInerney & McInerney, 1998). The data collection

and analysis have therefore been framed by these views. The analysis and assertions are a joint construction of both authors.

Results

The results are presented in the form of a reconstructed description of events that transpired during the series of meetings, with comments where appropriate. Where the first person is used, this is a comment or perception from the participant researcher (KA).

The First Meeting

After some initial clarification of the purpose of the meetings, the school context, and how we would work as a group, the planning task was presented to the teachers. They were a little uncomfortable with being given a content topic different from what they normally taught, but accepted the necessity to work and plan from "scratch" rather than work from one of their existing plans. The teachers then reviewed the "target" outcome for the unit which had been suggested: *Earth and Beyond* learning outcome 4.1[3], and the associated outcomes at the other levels of 2.1, 3.1 and 5.1. These outcomes are:

- 2.1 – Students identify and describe changes in the obvious features of the Earth and sky (including changes in the appearance of the moon).
- 3.1 – Students identify and describe some interactions (including weathering and erosion) that occur within systems on Earth and beyond.
- 4.1 – Students recognise and analyse some interactions (including the weather) between systems of Earth and beyond.
- 5.1 – Students explain how present-day features and events can be used to make inferences about past events and changes in Earth and beyond.

Sarah and Peter expressed doubt as to whether grade 7 students were capable of achieving Level 4 without the benefit of earlier work leading up to this outcome. Robyn referred to her experience with the National Curriculum in the United Kingdom, highlighting how the initial specification of outcomes was at too high a level and was later revised to what children could reasonably be expected to achieve. They decided to "target" outcome 3.1 since they felt that many students could not achieve level 4.1. This discussion showed that the teachers were confident that they had a good understanding of their students and what they could achieve. Their different perception of the students' capability from that suggested in the syllabus resulted in a loss of confidence in the appropriateness of the outcome specifications in the syllabus. However, my feeling was that many grade 7 students would be capable of achieving the outcome, given appropriate learning experiences. Perhaps the teachers' perceptions of the students' capability, not surprisingly, were based on their experience of teaching science based on the previous syllabus.

A number of other issues were canvassed as the teachers grappled with fitting the new syllabus requirements with their current practice. A key question was the role of subject integration in a syllabus based on outcomes: would the teachers' current practice of integrating science with other subjects be possible? They decided that it would be possible, though separate subject plans may need to be specifically prepared. I encouraged them to focus on a science plan first, since I felt that teachers who had a firm grasp of planning in science would then have a sound basis for integrating it with other subjects. I thought that if they tried to integrate subjects without understanding how to plan in science, this could result in programs which nominally included science, but were essentially non-science (Appleton & Kindt, 1997). Another issue which emerged was the teachers' felt need for a school plan

which mapped outcomes and content across the grades. None was yet available. This preference created a dilemma as the teachers also felt that teachers should have flexibility in their teaching and not be constrained by highly specific school documents. The issue was also related to the school curriculum adviser's concern that all school staff should preferably undertake professional development in science together, so that mutual support networks could be built. I noted this idea as one to revisit in the next phase of the study involving a whole school.

A first attempt at interpretation of the outcomes followed. The intent of this discussion was to reach agreement about how the outcomes for Levels 2, 3 and 4 differed (Level 5 was considered so far beyond the students' capability that it was not worth looking at). The outcomes in the final version of the syllabus differed considerably from those which had been in the draft version which the teachers had trialed, so they were not clear about the characteristics of the outcomes. This only emerged as the teachers talked about the outcomes and highlighted to us a difficulty of professional development providers: assuming that participants know something about official documentation and/or policy, when in fact there may be parts which are not known or are, at least, unclear. Once the characteristics of the outcomes were clarified[4], the teachers began to question which water cycle concepts and understandings might be related to the outcomes at the different levels. It quickly became apparent that none of the teachers had a deep understanding of the water cycle, which they admitted. Sarah and Robyn understood that phenomena such as evaporation and condensation were related to the topic, but were unsure how. Peter explained aspects of this, but did not elaborate in detail. The teachers' struggles with the scientific understandings influenced their ability to plan in two ways. First, they were unsure what the students might

learn from the unit, and second, they were not confident about being able to tell if a student was achieving at a particular level outcome, as they had no clear indicators for each. It was apparent to me that the teachers needed help through this.

Sarah provided some insights into how she dealt with any uncertainty in her understanding of content in a science unit she might be planning. She explained how she preferred to search for teacher resources that included student activity ideas, and peruse them. This both provided her with activity ideas for planning and helped her understand the science behind them. The activity descriptions themselves helped in this, but most helpful were activity ideas which included some background information for teachers. Peter agreed with this approach and described some student activity ideas which he knew and was comfortable with, though some of his suggestions were not highly relevant. It seemed as if he would rather use these activities in preference to trying to find some new ones, even though some of them were not relevant to the topic. Robyn said that she followed a similar procedure again comparing the Queensland material to that available in the United Kingdom. She felt that the UK materials provided much more background information for teachers and was more useful in planning. This discussion reminded me of the prominent place of "activities that work" in elementary school teachers' planning and implementation of science (Appleton & Doig, 1999). Peter's preference for using known activities, for instance, showed how he was willing to change the focus of the unit to avoid searching for new material.

This part of the discussion again highlighted the issue of elementary school teachers' science content knowledge, and their science pedagogical content knowledge (PCK). As Appleton and Kindt (1999) suggested, many teachers seem to use activities that work as a substitute for science PCK. Osborne and Simon (1996) highlighted how a teacher perused

printed resource materials containing activities to enhance her science content knowledge. It presented for me a dilemma which I had been anticipating: how to help these teachers with their science content knowledge and their science PCK, yet not get bogged down in a lot of science content so that the teachers felt they lost focus on their planning. At the end of the session, I offered to bring to the next session a list of understandings related to the topic for their consideration. This, I hoped, would provide a basic set of understandings which might generate some discussion and would be useful in the teachers' planning.

The teachers agreed that they now needed to review resources on the topic, and would bring them to the next meeting. Before the meeting concluded, some discussion ensued regarding suitable teaching approaches such as the 5Es[5] (Australian Academy of Science, 1994). All of the teachers indicated that they preferred using the 5Es approach.

Subsequent Meetings

The following week, the teachers commenced the session by describing in turn the activities that they had found. They then began to explore how to sequence them. This resulted in their revisiting the teaching approach to be adopted in the unit. They confirmed that they preferred the 5Es approach. After about three quarters of an hour, they again were confronted by the problem of what the students might learn from the unit: that is, the concepts or understandings which might match with the different level outcomes. Sarah indicated that she would like some questions to focus her teaching, such as "Where does water go when it evaporates?" This did not strike a chord with the other teachers. Peter said that he would want the students to explain how the water cycle works, but was unable to respond to my query about what type of explanations would fit with the different level

outcomes. Robyn agreed with the idea of needing to identify understandings the students might reach, but did not offer any suggestions.

In my judgement, each teacher had a better understanding of the water cycle than they had the previous week, which I would attribute to the knowledge they had gained from perusing the activity ideas they had found. I had prepared a list of understandings about the water cycle at several levels of complexity, and offered this for feedback to see whether it helped clarify their thinking about understandings related to the outcome levels. As the discussion about these progressed, it became clear that they would not entertain any understandings which referred to the molecular level. They justified this on the grounds that such ideas were too complex for the students, but Robyn revealed that it was too complex for her as well: "I would avoid that. I don't know enough about it." They agreed that the list which I provided was helpful in clarifying their thinking, but said that the listed understandings should be levelled against the outcomes for them to be useable. They decided to do this with the list provided, and in doing so became aware that the understandings listed also related to outcomes in other strands such as *Natural and Processed Materials*, and *Energy and Change*. The session concluded with a level of frustration among the teachers, because they felt that they had spent considerable time without showing much progress in their planning. They recognised that the time which they had spent was necessary in clarifying their own knowledge base, but also saw this as an imposition which busy teachers would never have the luxury of engaging in. They stated that the syllabus/curriculum materials should provide this type of knowledge resource for teachers in order to reduce the time demands on teachers' planning.

Herein lies another dilemma. We believe that the teachers' knowledge base was extended by the process of examining potential activities for the unit, the outcomes, and possible student understandings. That is, it was the **process** of thinking about these and how they might be used in teaching which was the main avenue for the development of their knowledge. If all this were provided in a "prepackaged" form in the syllabus and curriculum materials as they wanted, to what extent would their knowledge base grow from just reading it and following the "recipe"? This flagged for us another issue which we would later need to investigate.

In the final session, Robyn was absent. Sarah and Peter resumed their discussion of the sequence of activities, and the activities that they would use. Within a short time they had agreed on a set of activities, and how they would be sequenced using the selected teaching approach steps. However, they did not refer further to the list of understandings in their planning; though they seemed to be organising the activities with some of these in mind. There was considerable discussion about whether the unit as planned would allow students to demonstrate achievement in *Earth and Beyond* outcome 4.1, which led to them again exploring what the wording of the outcome meant (specifically, what "between systems" meant). They also discussed whether an outcome could be demonstrated by a student from one piece of content (eg a science topic like "the water cycle"), or whether a student would have to demonstrate the outcome using more than one area of content (eg the water cycle and global warming). I explained that a basic assumption behind the outcomes is that they can be demonstrated by students through different content, but what this idea meant in practice remained unclear to these teachers.

The discussion moved onto assessment. The teachers drew upon practices they currently employed in mathematics and language, which would allow the compilation of individual portfolios. I asked for clarification about how they would make judgements about students' level of achievement, but this had not been a part of their thinking. I asked whether the list of levelled understandings would be of use in helping them reach decisions about students' level of achievement, and this received qualified support. It seemed as if they had reverted to their old patterns of planning without detailed consideration of specific understandings which students may learn. Even the discussion about assessment had not made this consideration an imperative for them. Their qualified support of my suggestion made us wonder to what extent they would be able to use the listed understandings in their portfolio assessment. That is, would they be happy with just collecting student artefacts, or would they also explore the student understandings which the artefacts revealed?

From previous work, I had postulated that one way forward for elementary school teachers was to provide plans of "units that work" (Appleton & Doig, 1999). I introduced this idea and asked for feedback as to whether teachers would find such units helpful. Peter thought it would be very helpful to teachers in general, and would even be useful to him. Sarah gave qualified agreement, but was concerned that teachers would, by default, become locked into a restricted curriculum based on the units provided. Peter suggested that a sample of units could be provided so teachers could see how they were prepared, and could then plan their own units of work from scratch.

Finally, I introduced the issue of what sort of professional development experiences they would recommend for less science-experienced teachers trying to implement the new

syllabus. In light of the planning experience they had just been through, they suggested three foci for professional development:

- Familiarisation with the syllabus and the support material; and its constructivist basis (half day).
- Using a pre-prepared model unit plan, showing how the unit plan was prepared, with explanations as to why each part was included and the significance of any sequence (2 hours).
- The teachers preparing their own unit plan using the modelled unit plan as a template, with support as required (2 hours).

In response to my query about pedagogical support as well, Peter insisted that they needed no help in how to teach: "Don't tell us how to teach. We know how to do that." I wondered whether this belief was a misperception, or whether these teachers had successfully adjusted their teaching to be consistent with the syllabus as a consequence of their involvement in the syllabus trial. I also wondered to what extent other teachers would feel the same, even if they had not had the benefit of the syllabus trial. Certainly, the available research suggests that many teachers do not have activity-based science strategies as part of their teaching repertoire (eg Appleton & Kindt, 1997). Peter consequently did not believe that teachers would want to teach from any model unit plans which may be provided, but would rather teach from their own unit plans which they had themselves devised.

The teachers suggested, in response to my question, that any model unit plan should include a highly focused list of understandings which would serve as indicators of students' achievement in the outcomes. I was concerned that the teachers thought that constructivist ideas could be dealt with in a short one to one and a half hour session. Peter's comment that

constructivism was "finding out what the children know" revealed that he had derived a limited understanding of constructivism from the trial syllabus workshops. Yet his point about available time for professional development and ensuring that participating teachers remained interested highlighted how it may not be possible to go much beyond this understanding in the early phases of professional development.

Discussion

This joint planning experience provided us a number of insights regarding professional development support for the new syllabus, as well as how some elementary school teachers plan for teaching science. The following are several assertions which, in our judgement, emerge from the data.

An Early Phase of Planning is Gathering of Activity Ideas

By the end of the first session the teachers were uncomfortable about planning further without searching for and perusing activities that may be relevant to the topic. They later commented that this was a common planning framework for all subjects, which they had recognised within the school during the syllabus trial. This is consistent with the importance of activities that work in teachers' minds, and figured in earlier work (Appleton & Kindt, 1997; Appleton & Doig, 1999) as well as other studies (eg Osborne & Simon, 1996). We suggest that this part of teachers' planning processes should play a significant role in science professional development.

Science Content Knowledge is Supplemented by Activities

All three teachers gained or clarified their personal science content knowledge regarding water cycle concepts from perusing the activities they had gathered. This was evident from their tentative statements about the concepts in the first session, compared to

their clearer articulation of ideas in the second. However, they did not extend their knowledge base much beyond that which was explained in the activity descriptions, and which the students may therefore have acquired by engaging in the activity. The source of this content knowledge was the activities they had collected, which they used to build upon their existing knowledge base. It is pertinent to note that all of the teachers commenced the exercise with an existing knowledge base regarding the water cycle, but that it was imprecise and certainly was not clearly articulated. This may have been due to a reluctance by the teachers to say too much in case they made a public statement about the content which could be shown incorrect. In any professional development, there therefore needs to be a process where participating teachers' existing knowledge is clarified and affirmed; and they are given the opportunity to extend that knowledge without explicitly focusing on any gaps in their knowledge. For instance, there could be a focus on student misconceptions and what the students might learn, as suggested by Osborne and Freyberg (1985). Reference to activity ideas may be another way of doing this, and/or consideration of the understandings which might emerge from students' engaging in such activities, and which link to learning outcomes. The latter idea is an imperative if teachers are to be able to work with an outcomes based syllabus: they need to know the specific understandings that students might achieve which bridge the gap between the activities they engage in and the syllabus outcomes.

However, the knowledge gained by the teachers in this instance was not extensive enough to provide them with a strong basis for knowing how to determine whether understandings which might be developed by students were indicative of particular outcomes. This raises the question of how much content knowledge is sufficient for teachers to be able to teach science effectively.

Science PCK is Bound Up in Activities

It was noticeable that in the three planning sessions, almost all talk that could be identified as science pedagogical content knowledge (PCK) was in terms of activity ideas. That is, specific aspects of teaching science were described in terms of activities. However, the activity ideas were not just descriptions of what the students would engage in; they also included teaching strategies, management ideas, and in some cases questions to ask the students. Hence these teachers' PCK was not confined to the activity descriptions they had gleaned from books and the internet. These descriptions were augmented by the teachers using their own pedagogic knowledge. This may be part of what Peter meant when he said that any professional development should not tell him how to teach. Given that the teachers also extended and clarified their own science content knowledge through the activities they had found, this may have enabled them to work with their general pedagogic knowledge to develop from the activities personal science PCK.

In an earlier study (Appleton & Kindt, 1999), I had postulated that activities that work may be a substitute for science PCK for at least some elementary teachers. This was only partially true for these teachers, and perhaps "substitute" is the wrong word for them. Their science PCK for this topic was inextricably bound up with the activities they had found because the activities had been used to enhance their science content knowledge and their science teaching ideas. However, their science PCK was not limited to just the activities since they had used their extensive general pedagogic knowledge to extend the activity material.

Cooperative Planning Assists Teacher Learning

Given our personal orientation toward social constructivist ideas about learning, we had designed this pilot study so that the teachers would be working in a group on a cooperative planning exercise. We also saw this as the beginning of a potential future direction of ongoing professional support within the school. The nature of the transactions between the teachers when they were planning confirmed our belief that cooperative work enhances teacher-learning. For instance, it was the process of discussing student understandings related to outcomes that clarified and pushed the teachers' content knowledge beyond what they had gained from just reading the activity ideas. The sharing of activity ideas and understandings about aspects of the water cycle also enabled the teachers to identify gaps in their science content knowledge and science PCK as well as extend their knowledge. The teachers had also discussed some ideas during the weeks between meetings, suggesting that mutual support networks may be a means of providing ongoing professional support. Sarah commented, for instance, that they had deliberately restricted discussion during the week because they were aware that we were wanting to capture their discussions during our regular meetings. While some teacher professional development can obviously occur individually and via teachers working with their classes, working cooperatively with other teachers in a structured learning environment provides opportunities for learning that are not readily available in other ways.

Curriculum Materials Should Provide Information Which Assists Teachers

While it may seem self-evident that a syllabus and support material should provide information that assists teachers, this does not always happen as made clear by these teachers. It quickly became apparent that the material provided within the syllabus was

inadequate for the three teachers. This was not unexpected as we had identified similar difficulties when preparing the content for the CDROM to be distributed to teachers (Education Queensland, 1999). While it was the intent of the syllabus project team to provide material which would help teachers (personal communication), political positions within the QSCC and the fact that this was the first outcomes based syllabus in Queensland, have had an effect. There is a dilemma here: if sets of concepts are defined, then these can become a *de facto* syllabus for teachers, and the flexibility afforded an outcomes approach is lost. On the other hand, unless elementary school teachers are provided with the support that sets of concepts/understandings give, they are not able to plan effectively toward outcomes. Given that the teachers in this study were experienced and confident in science, we do not think many elementary school teachers would be able to plan adequately with the material provided by QSCC.

If elementary school teachers in Queensland are to implement the new science syllabus effectively, they urgently need supplementary information which provides conceptual ideas which link content to the different level outcomes – even at the risk of generating a *de facto* syllabus centred around these conceptual ideas. While the teachers in this study suggested that such a list should be part of a model unit plan used in professional development, the need for other lists would occur when they began planning their own units. At present we see no clear way past this dilemma. Further, these teachers felt that others would not want model unit plans to implement, but would rather develop their own. However, we believe that many teachers would welcome some model unit plans in selected areas of science where they particularly lack confidence. This is an area for future research.

Assessment Issues Need Clarification

Assessment emerged as an important issue for these teachers. Superficially at least, their concerns were resolved by their calling upon assessment practices used in other subjects. However, I am not convinced that the teachers were able to apply these practices to the outcomes context, and in particular to identifying student understandings which might indicate performance at different outcome levels. Interestingly, assessment was not nominated by the teachers to be included in an initial professional development program for teachers. We believe that assessment issues would probably be raised during planning components of the proposed professional development session, but recognise that there would be insufficient time to deal with it adequately. Further research will be necessary to clarify whether assessment can be left for a follow up professional development session, or whether it should be incorporated into the initial program.

Principles for Professional Development

A tentative set of principles for provision of professional development to support the implementation of the new syllabus emerged from the study, though aspects remain unclear and require further clarification. A constraint of the professional development provision was that it needed to fit within the personnel availability and cost restrictions of the local Catholic Education system, particularly when taken to schools in remote areas. For instance, even if funds were available for replacement teachers, some remote schools would be able to find only one or two replacement teachers, making large-scale or school-based professional development sessions impractical. This constraint was implicit in our discussions with the teachers.

Principle 1

Provide an initial professional development program which is short, highly focused, and maintains teachers' interest. An initial professional development program of about seven to eight hours was nominated by the teachers as appropriate for most teachers. This would have three phases consisting of:

1. an orientation to the syllabus which identifies the main components of levelled outcomes, working scientifically, and constructivist ideas of learning;
2. an examination of a model unit plan with an explanation of how it was constructed, which would include consideration of the activities used, the teaching approach employed, and the understandings which could be used as indicators of student achievement of the outcomes; and
3. a cooperative planning session where teachers plan their own science units of work, with assistance. A key component of this assistance would be to ask teachers to consider the understandings associated with the outcomes which could serve as indicators of student achievement and would bridge the conceptual gap between the activities and outcomes.

Principle 2

Embed the professional development in the teachers' workplace. An important framework for the third phase mentioned above, would be using the school science plan as a basis for the teachers' planning. The detail of how student understandings in selected content areas align with level outcomes would require further clarification as this would not normally be a component of a school plan. Any science units planned should be useable by the teachers in their classrooms.

Principle 3

Cooperative networks should be part of the professional development environment. A key component of the professional development was working cooperatively with other teachers, especially in planning.

Principle 4

Provide ongoing support. This would particularly be needed in:

1. further exploration of teaching using constructivist ideas of learning;
2. help with specific aspects of science content;
3. assistance in finding a range of activity ideas;
4. exploration of effective ways of assessing and reporting student achievement in terms of the outcomes; and
5. in-class support for trying different teaching strategies and approaches.

Principle 5

Finally, the syllabus and support material need to be supplemented by material which the teachers find useful. While this is not what might normally be considered a component of professional development, its absence in this case has implications for the nature of professional development which supports teachers trying to implement the new syllabus. For instance, should effort be put into using units that teachers develop in phase three above as a basis for the development of model units which other teachers could use? If so, what professional development, if any, is necessary to help teachers use such materials effectively? Further, given that student understandings linked to content and outcomes is not available, should this be provided as supplementary support material?

Conclusion

In this pilot study we had not attempted to observe the teachers implementing the unit plan which they had prepared. However, it was apparent that this would be a necessary component of further research into the trials of the professional development program provided for teachers. A focus of this component of the research would need to be on the teachers' effective use of constructivist-based pedagogy, the extent that teachers focus on enhancing students' conceptual learning related to the outcomes, and determining student learning.

This study has clarified some aspects of science PCK for experienced elementary school teachers, and given directions for providing professional development to support the implementation of a new outcomes based science syllabus. A number of dilemmas in professional development support have been identified, which will lead to compromises and the need for long-term professional support. This is a key cost issue for the education system. The relationship between activities and science PCK for less experienced and less confident teachers needs further clarification and study. This pilot study has also provided directions for future research in trialing the suggested professional development program and in exploring whether model unit plans are helpful to other less-confident teachers.

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Footnotes

1. Elementary school in Queensland, usually referred to as primary school, covers Years (grades) 1 to 7 – that is, children aged 5 to 12 years. There is a voluntary preschool year for children aged four years.
2. The syllabus was introduced only a few months prior to the commencement of the study.
3. The first numeral indicates the level of the outcome. The syllabus has six levels across the ten years of compulsory schooling, with the expectation that Level 4 should be achieved by the end of grade 7, Level 5 by the end of grade 9, and Level 3 by the end of grade 5. The second, decimal numeral indicates the sequence of the outcomes in the concept area or strand.
4. The Queensland syllabus outcomes state what students should know and be able to do. They contain words which reflect working scientifically, and others which suggest conceptual understanding.
5. The 5Es approach, originally derived from SCIS, is named after the five steps of engage, explore, explain, elaborate, and evaluate. The syllabus support material (QSCC, 1999b) emphasises planning a unit of work structured around an overall teaching approach such as 5Es or the Interactive Approach (Biddulph & Osborne, 1984; Appleton, 1993).

VIEWS OF NATURE OF SCIENCE QUESTIONNAIRE (VNOS): TOWARD VALID AND MEANINGFUL ASSESSMENT OF LEARNERS' CONCEPTIONS OF NATURE OF SCIENCE

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During the past 85 years, almost all scientists, science educators, and science education organizations have agreed upon the objective of helping students develop informed conceptions of nature of science (NOS) (Abd-El-Khalick, Bell, & Lederman, 1998). Presently, and despite their varying pedagogical or curricular emphases, there is agreement among the major reform efforts in science education (American Association for the Advancement of Science [AAAS], 1990, 1993; National Research Council [NRC], 1996) around the goal of enhancing students' conceptions of NOS. However, research has consistently shown that K-12 students, as well as teachers, have not attained desired understandings of NOS (e.g., Abd-El-Khalick & Lederman, 2000a; Duschl, 1990; Lederman, 1992). Several attempts have been, and continue to be, undertaken to enhance students and science teachers' NOS views (e.g., Akerson, Abd-El-Khalick, & Lederman, 2000; Billeh & Hasan, 1975; Carey & Stauss, 1967, 1968; Carey, Evans, Honda, Jay, & Unger, 1989; Haukoos & Penick, 1983, 1985; Jelinek, 1998; Ogunniyi, 1983; Olstad, 1969; Shapiro, 1996; Scharmann & Harris, 1992; Solomon, Duveen, & Scot, 1994).

Nevertheless, the assessment of learners' views of the scientific endeavor remains an issue in research on NOS (Lederman, Wade, & Bell, 1998). In the greater majority of the aforementioned efforts, standardized and convergent paper-and-pencil instruments have been used to assess learners' NOS views. Several problematic assumptions underlie such instruments and cast doubt on their validity. Moreover, there are several concerns regarding the usefulness of

standardized instruments for research related to NOS. The purpose of this paper is to (a) trace the development of a new instrument, the *Views of Nature of Science Questionnaire* (VNOS), which in conjunction with individual interviews, aims to provide authentic and meaningful assessments of learners' NOS views, (b) elucidate the use of the *VNOS* and associated interviews, and the range of NOS aspects that it aims to assess, (c) present evidence regarding the validity of the *VNOS*, and (d) discuss the usefulness of rich descriptive NOS profiles that the *VNOS* provides in research related to the teaching and learning of NOS. However, before discussing the *VNOS*, we will outline the NOS framework that underlies its development, and delineate the problematic nature of standardized and convergent type paper-and-pencil NOS instruments.

NOS

Typically, NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development (Lederman, 1992). These characterizations, nevertheless, remain fairly general, and philosophers, historians, and sociologists of science are quick to disagree on a specific definition for NOS. Such disagreement, however, should not be surprising or disconcerting given the multifaceted and complex nature of the scientific enterprise. Moreover, similar to scientific knowledge, conceptions of NOS are tentative and dynamic. These conceptions have changed throughout the development of science and systematic thinking about its nature and workings (Abd-El-Khalick & Lederman, 2000a).

It is our view, however, that many of the disagreements about the specific definition or meaning of NOS that continue to exist among philosophers, historians, sociologists, and science educators are irrelevant to K-12 instruction. The issue of the existence of an objective reality as compared to phenomenal realities is a case in point. Moreover, at one point in time and at a

certain level of generality, there is a shared wisdom (even though no complete agreement) about NOS amongst philosophers, historians, and sociologists of science (Smith, Lederman, Bell, McComas, & Clough, 1997). For instance, presently, it would be very difficult to reject the theory-laden nature of scientific observations and investigations, or to defend a deterministic/absolutist or empiricist conception of NOS. At such a level of generality, some important aspects of NOS are non-controversial. Some of these latter aspects, which we believe are accessible to K-12 students and relevant to their daily lives, were adopted and emphasized for the purpose of developing the *VNOS*. These aspects are that scientific knowledge is: tentative, empirically-based, subjective (theory-laden), partly the product of human inference, imagination, and creativity, and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the lack of a universal recipe-like method for doing science, and the functions of, and relationships between scientific theories and laws. It should be noted that these NOS aspects have been emphasized in recent science education reform documents (e.g., AAAS, 1990, 1993; NRC, 1996).

In this regard, it is crucial to note that individuals often conflate NOS with science processes. In agreement with the reform documents (AAAS, 1990, 1993; NRC, 1996), we consider scientific processes to be activities related to the collection and interpretation of data, and the derivation of conclusions. NOS, by comparison, is concerned with the values and epistemological assumptions underlying these activities (Abd-El-Khalick et al., 1998). For example, observing and hypothesizing are scientific processes. Related NOS conceptions include the understandings that observations are constrained by our perceptual apparatus, that the generation of hypotheses necessarily involves imagination and creativity, and that both activities

are inherently theory-laden. Although there is overlap and interaction between science processes and NOS, it is nevertheless important to distinguish the two.

Before turning to briefly discuss the aforementioned NOS aspects, it should be emphasized that the generalizations presented in this discussion should be construed in the context of K-12 science education, rather than the context of educating graduate students in philosophy or history of science. Moreover, it should be noted that in the context of K-12 education, each of these NOS aspects could be approached at different levels of depth and complexity depending on the background and grade level of students.

The Empirical Nature of Scientific Knowledge

Science is, at least partially, based on and/or derived from observations of the natural world, and "sooner or later, the validity of scientific claims is settled by referring to observations of phenomena" (AAAS, 1990, p. 4). However, scientists do not have "direct" access to most natural phenomena. Observations of the natural world are always filtered through our perceptual apparatus and/or intricate instrumentation, interpreted from within elaborate theoretical frameworks, and almost always mediated by a host of assumptions that underlie the functioning of "scientific" instruments.

Observation, Inference, and Theoretical Entities in Science

All students should be able to distinguish between observation and inference. Observations are descriptive statements about natural phenomena that are directly accessible to the senses (or extensions of the senses) and about which several observers can reach consensus with relative ease. For example, objects released above ground level tend to fall to the ground. By contrast, inferences are statements about phenomena that are not directly accessible to the

senses. For example, objects tend to fall to the ground because of "gravity." The notion of gravity is inferential in the sense that it can only be accessed and/or measured through its manifestations or effects. Examples of such effects include the perturbations in predicted planetary orbits due to inter-planetary "attractions," and the bending of light coming from the stars as its rays pass through the sun's "gravitational" field.

An understanding of the crucial distinction between observation and inference is a precursor to making sense of a multitude of inferential and theoretical entities and terms that inhabit the worlds of science. Examples of such entities from the physical sciences include atoms, molecular orbitals, photons, magnetic fields, and gravitational forces. Theoretical entities also abound in the biological sciences, such as the concept of species, which "like the terms 'gene,' 'electron,' 'non-local simultaneity,' and 'element,' is a theoretical term embedded in a significant scientific theory" (Hull, 1998, p. 146).

Scientific Theories and Laws

Scientific theories are well-established, highly substantiated, internally consistent systems of explanations (Suppe, 1977). Theories serve to explain relatively huge sets of seemingly unrelated observations in more than one field of investigation. For example, the kinetic molecular theory serves to explain phenomena related to changes in the physical states of matter, the rates of chemical reactions, and still other phenomena related to heat and its transfer. More importantly, theories play a major role in generating research problems and guiding future investigations.

Scientific theories are often based on a set of assumptions or axioms and often posit the existence of non-observable entities. As such, theories cannot be directly tested. Only indirect evidence can be used to support theories and establish their validity. To test theories (or

hypotheses), scientists derive specific testable predictions from those theories (or hypotheses) and check them against tangible data. An agreement between such predictions and empirical evidence serves to increase the level of confidence in the tested theory (or hypothesis).

Closely related to the distinction between observation and inference is the distinction between scientific laws and theories. Generally speaking, scientific laws are statements or descriptions of the relationships among observable phenomena. Boyle's law, which relates the pressure of a gas to its volume at a constant temperature, is a case in point. Scientific theories, by contrast, are inferred explanations for observable phenomena or regularities in those phenomena. The kinetic molecular theory, which explains Boyle's law, is one example. Students often hold a simplistic, hierarchical view of the relationship between theories and laws whereby theories become laws depending on the availability of supporting evidence. Moreover, those students believe that scientific laws have a higher status than scientific theories. Both notions, however, are inappropriate. Theories and laws are different kinds of knowledge and one does not become the other. Theories are as legitimate a product of science as laws. Scientists do not usually formulate theories in the hope that some day they would acquire the status of "law."

The Creative and Imaginative Nature of Scientific Knowledge

Science is empirical. The development of scientific knowledge involves making observations of natural phenomena. Nonetheless, generating scientific knowledge also involves human imagination and creativity. Science, contrary to common belief, is not a lifeless, completely rational, and orderly activity. Science involves the invention of explanations and theoretical entities, which requires a great deal of creativity on the part of scientists. The "leap" from atomic spectral lines to Bohr's model of the atom with its elaborate orbits and energy levels is a case in point. This aspect of science, coupled with its inferential nature, entails that scientific

entities, such as atoms and species, are functional theoretical models rather than faithful copies of "reality."

The Subjective and Theory-laden Nature of Scientific Knowledge

Scientific knowledge is subjective or theory-laden. Scientists' theoretical and disciplinary commitments, beliefs, previous knowledge, training, experiences, and expectations actually influence their work. All these background factors form a mind-set that affects the problems scientists investigate and how they conduct their investigations, what they observe (and do not observe), and how they make sense of, or interpret their observations. It is this (sometimes collective) individuality or mind-set that accounts for the role of subjectivity in the production of scientific knowledge. It is noteworthy that, contrary to common belief, science never starts with neutral observations (Popper, 1992). Observations (and investigations) are always motivated and guided by, and acquire meaning in reference to questions or problems. These questions or problems, in turn, are derived from within certain theoretical perspectives.

The Social and Cultural Embeddedness of Scientific Knowledge

Science as a human enterprise is practiced in the context of a larger culture and its practitioners (scientists) are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion. An example may help to illustrate how social and cultural factors impact scientific knowledge. Telling the story of the evolution of humans (*Homo sapiens*) over the course of the past 7 million years is central to the biosocial sciences. Scientists have formulated several elaborate and differing storylines about this evolution. Until recently, the

dominant story was centered about "the man-hunter" and his crucial role in the evolution of humans to the form we now know (Lovejoy, 1981). This scenario was consistent with the white-male culture that dominated scientific circles up to the 1960s and early 70s. As the feminist movement grew stronger and women were able to claim recognition in the various scientific disciplines, the story about hominid evolution started to change. One story that is more consistent with a feminist approach is centered about "the female-gatherer" and her central role in the evolution of humans (Hrdy, 1986). It is noteworthy that both story lines are consistent with the available evidence.

Myth of "The Scientific Method"

One of the most widely held misconceptions about science is the existence of "The Scientific Method." The modern origins of this misconception could be traced back to Francis Bacon's *Novum Organum* (1620/1996) in which the inductive method was propounded to guarantee "certain" knowledge. Since the 17th century, inductivism and several other epistemological stances that aimed to achieve the same end (although in these latter stances the criterion of "certainty" was either replaced with notions of "high probability" or abandoned altogether), such as Bayesianism, falsificationism, and hypothetico-deductivism, have been debunked (Gillies, 1993). Nonetheless, some of these stances, especially inductivism and falsificationism, are still widely popularized in science textbooks and even explicitly taught in classrooms. The myth of "The Scientific Method" is regularly manifested in the belief that there is a recipe-like stepwise procedure that all scientists follow when they "do" science. This notion was explicitly debunked by the *National Science Education Standards* (NRC, 1996) and *Benchmarks for Science Literacy* (AAAS, 1993). There is no single "Scientific Method" that would guarantee the development of infallible knowledge (Bauer, 1994; Lederman, Farber, Abd-

El-Khalick, & Bell, 1998; Shapin, 1996). It is true that scientists observe, compare, measure, test, speculate, hypothesize, create ideas and conceptual tools, and construct theories and explanations. However, there is no single sequence of activities (prescribed or otherwise) that will unerringly lead them to functional or valid solutions or answers, let alone "certain" or "true" knowledge.

The Tentative Nature of Scientific Knowledge

Scientific knowledge, though reliable and durable, is never absolute or certain. This knowledge, including "facts," theories, and laws, is subject to change. Scientific claims change as new evidence, made possible through advances in theory and technology, is brought to bear on these claims, and as extant evidence is reinterpreted in the light of new theoretical advances, changes in the cultural and social spheres, or shifts in the directions of established research programs. It should be emphasized that tentativeness in science does not solely arise from the fact that scientific knowledge is inferential, creative, and socially and culturally embedded. There are also compelling logical arguments that lend credence to the notion of tentativeness. Indeed, contrary to common belief, scientific hypotheses, theories, and laws can never be absolutely "proven." This holds irrespective of the amount of empirical evidence gathered in the support of one of these ideas or the other (Popper, 1963, 1988). For example, to be "proven," a certain scientific law should account for every single instance of the phenomenon it purports to describe at all times. It can logically be argued that one such future instance, of which we have no knowledge whatsoever, may behave in a manner contrary to what the law states. As such, the law can never acquire an absolutely "proven" status. This equally holds in the case of hypotheses and theories.

Problematic Nature of Standardized and Convergent Paper-and-Pencil NOS Instruments

During the past 40 years, more than 20 standardized and convergent paper-and-pencil instruments have been developed to assess learners' NOS views (Lederman et al., 1998). Examples of such instruments include *Test on Understanding Science* (Cooley & Klopfer, 1961), *Science Process Inventory* (Welch & Pella, 1967-68), *Nature of Science Scale* (Kimball, 1967-68), *Nature of Science Test* (Billeh & Hasan, 1975), *Conceptions of Scientific Theories Test* (Cotham & Smith, 1981), and *Modified Nature of Scientific Knowledge Scale* (Meichtry, 1992). These instruments comprised forced-choice, such as agree/disagree, Likert-type or multiple-choice items.

Many criticisms have been leveled against the use of standardized instruments to assess learners' NOS views. Two major criticisms were related to these instruments' validity. First, Aikenhead, Ryan, and Desautels (1989) and Lederman and O'Malley (1990) argued that such instruments were all based on a problematic assumption. These instruments *assumed* that respondents perceive and interpret an instrument's items in a manner similar to that of the instrument developers. Lederman and O'Malley argued that ambiguities, which seriously threaten these instruments' validity, result from assuming that respondents understand a certain statement in the same manner that the researchers or instrument developers would, and agree or disagree with that statement for reasons that coincide with those of the researchers or instrument developers. Second, Lederman et al. (1998) noted that standardized instruments usually reflected their developers' views and biases related to NOS. Being of the forced-choice category, these instruments ended up imposing the researchers' or developers' own views on the respondents. Additionally, responses to instrument items were usually designed with various philosophical stances in mind. As such, irrespective of the choices the respondents made, they often ended up

being labeled as if they firmly held coherent, consistent philosophic stances such as inductivist, verificationist or hypothetico-deductivist (e.g., Dibbs, 1982; Hodson, 1993). Thus, the views that ended up being ascribed to respondents were more an artifact of the instrument in use than a faithful representation of the respondents' conceptions of NOS.

A third criticism relates to the usefulness of standardized instruments. These instruments were mainly intended to label participants' NOS views as "adequate" or "inadequate"—mostly by assigning those views cumulative numerical values—rather than elucidating and clarifying such views. What is more, researchers and instrument developers never clarified what numerical value on such instruments constituted an "adequate" view of NOS (Lederman, 1986). As such, the use of standardized instruments severely limits the feasibility of drawing meaningful conclusions regarding learners' NOS views and/or assessing the meaningfulness and importance of any gains in understanding NOS achieved by learners as a result of various instructional interventions. Indeed, the use of standardized and convergent NOS assessment instruments is more commensurate with the largely abandoned inputs-outputs behavioristic approach to teaching and learning than with the cognitive constructivist approach that is currently widely endorsed by science educators.

Development of the *VNOS*

VNOS–Form A

In response to the discussed state of affairs, Lederman and O'Malley (1990) developed a seven-item open-ended questionnaire, which they intended to use in conjunction with follow-up individual interviews to assess high school students' views of the tentative NOS. The questionnaire consisted of the following seven items:

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories change, explain why we bother to learn about theories. Defend your answer with examples.

2. What does an atom look like? How do scientists know that an atom looks like what you have described or drawn?

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

5. Scientists perform scientific experiments/investigations when trying to solve problems. Do scientists use their creativity and imagination during these experiments/investigations?

6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

7. Some astrophysicists believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

The use of an open-ended questionnaire was intended to avoid the problems inherent in the use of standardized forced-choice instruments. In contrast to forced-choice items used in convergent style instruments, open-ended items allow respondents to elucidate their own views regarding the target aspects of NOS and the reasons that underlie their views. Moreover, given the concern with the meanings that participants ascribed to the target NOS aspects, and the researchers' interest in elucidating and clarifying participants' NOS views rather than simply labeling or judging them, it was imperative to avoid misinterpreting participants' responses to the

questionnaire. As such, individual semi-structured interviews were used to substantiate the validity of the researchers' interpretations of participants' responses as well as establish the face validity of the questionnaire items. The interviews also aimed to generate in-depth profiles of participants' NOS views. During these interviews, participants were provided their questionnaires (pre and post academic year) and asked to read, explain, and justify their responses. By asking respondents to elaborate and/or justify their answers, the researchers were able to assess not only respondents' positions on certain issues related to NOS, but the respondents' reasons for adopting those positions as well.

Lederman and O'Malley (1990) found that inferences drawn regarding participants' NOS views from 3 of the 7 open-ended questionnaire items were not validated during the interviews. Participants were either unable to interpret the intended meaning of these three items or found the items to be vague. These were items 4, 5, and 6 and were eliminated from final analyses. For example, item 5 was intended to assess whether students believed scientists used any creativity or imagination in the interpretation of data, or whether they believed the process to be totally objective. The data indicated that students simply considered the planning of the investigation. That is, students typically believed that scientists needed to be creative to design investigations. In short, students' responses clearly showed that the item did not assess the intended students' beliefs. These results, and others, corroborated the earlier arguments regarding the inadequacies associated with using standardized paper-and-pencil instruments as the sole means to assess learners' NOS views. In this "first attempt," the researchers reported inferences based on participants' responses to the remaining four items (items 1, 2, 3, and 7), whose validity was generally substantiated during individual interviews. But, even with these items, the problem of researchers' misinterpreting students' responses could not have been avoided without interviews.

For example, in responses to item 3, students consistently used the word "prove" when distinguishing laws and theories. This led the researchers to conclude that students held absolutist views of scientific knowledge. However, during the interviews, it became clear that students did not use the word "prove" in an absolute sense at all. Indeed, their use of the term was quite consistent with the way scientists use it. So, although the item was valid in its assessment of targeted student views, interpretation of student meaning (without interviews) led to the wrong conclusion by the researchers. These results provided further support for the importance of using follow-up interviews whenever paper-and-pencil NOS assessments are used. The open-ended questionnaire used by Lederman and O'Malley represented an initial attempt to validly assess students' perceptions and was systematically changed based on student responses in an attempt to improve validity. This first questionnaire is considered the first form of the *VNOS* instrument (*VNOS–A*).

<u>VNOS–Form B</u>

Abd-El-Khalick et al. (1998) revised some of the *VNOS–A* items and used this form of the instrument (Form B) to assess preservice secondary science teachers' views of the tentative, empirical, inferential, creative, and subjective NOS, as well as the functions of, and relationships between theories and laws. Initially, the administration of the *VNOS–B* (see Figure 1) was intended to elicit participants' views about some NOS aspects and create a context in which these views could be discussed. This administration was followed with in-depth individual interviews with all participant teachers. During these interviews, participants were provided their questionnaires and asked to read and explain their responses. Participants were asked to clarify the meanings they ascribed to key terms, such as "creativity," "opinion," and "evidence," and provide specific examples to illustrate and contextualize their views. Follow-up and probing

VNOS–Form B

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples.

2. What does an atom look like? How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.

6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

7. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

Figure 1. Views of Nature of Science Questionnaire (Form B)

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questions were also used to clarify vague statements or seeming contradictions in participants' responses. In a sense, the researchers were "learning to read" responses to the *VNOS-B* from the participants' perspectives.

The *VNOS–B* was used in subsequent studies with preservice secondary science teachers (Bell, Lederman, & Abd-El-Khalick, 2000) and preservice elementary teachers (Akerson, Abd-El-Khalick, & Lederman, 2000; Akerson & Abd-El-Khalick, 2000). In these studies, evidence regarding the validity of the instrument started to emerge. It became apparent that the researchers' interpretations of participants' views based on analyses of the *VNOS–B* responses

were mostly congruent with views expressed by those participants during individual interviews. Indeed, the *VNOS–B* was sensitive to recurrent patterns and themes, idiosyncrasies, as well as subtle changes in participants' NOS views. Nonetheless, subtle differences in the specific meanings that participants in each of these studies assigned to a certain NOS aspect were observed. Follow-up interviews remained crucial for valid interpretations of participants' responses to the questionnaire. However, as the researchers became more cognizant of the meanings that participant preservice teachers ascribed to key terms and phrases, and developed more expertise in interpreting participants responses, it was apparent that it was not imperative to interview *all* participants following an administration of the *VNOS–B*. Depending on the sample size, the researchers were now obtaining redundant meanings, categories, and themes (Lincoln & Guba, 1985) from interviews with 15-20% of participants.

Establishing the Construct Validity of the *VNOS–B*

A recent investigation (Bell, 1999) into the decision making of NOS experts and non-experts provided an excellent opportunity to assess the construct validity of the *VNOS–B*. If the instrument had construct validity, then respondents with assessed thorough understandings of NOS should respond much differently than those assessed to possess naïve understandings. A sample of adults was purposively selected to participate in the study. Secondary students were not selected for the principle reason that the nature of the study required one group to have expert understandings of NOS. This criterion ruled out the vast majority of, if not all, adolescents (Aikenhead, 1973, 1987; Bady, 1979; Gilbert, 1991; Lederman & O'Malley, 1990; Mackay, 1971; Rubba & Anderson, 1978; Wilson, 1954). The Expert group comprised nine individuals with doctoral degrees in science education, history of science or philosophy of science. Individuals in these fields may reasonably be expected to have developed NOS understandings

consistent with those espoused by current reform efforts. Members of the Novice group were purposively selected to be comparable to those of the Expert group, except for their expected levels of NOS understandings. These nine individuals had comparable educational backgrounds, but their doctoral degrees were in fields, such as American literature, history, and education, in which they were less likely to have contemplated the nature of scientific knowledge.

Each participant completed the *VNOS–B*. The completed questionnaires were first used to generate summaries of each participant's views. Next, the summaries were searched for patterns and/or categories. These categories were then checked against confirmatory or otherwise contradictory evidence in the data and modified accordingly. Several rounds of category generation, confirmation, and modification were conducted to satisfactorily reduce and organize the data. The categories were then used to construct preliminary profiles of participants' NOS views. After the analysis of the questionnaire responses was completed, participants were individually interviewed to provide them with opportunities to clarify and elaborate on their written responses. They were asked to explain their responses to each item and to respond to requests for clarification or elaboration. The interviews lasted approximately 45 minutes. All interviews were audiotaped and transcribed for analysis. The interview transcripts were first reviewed in order to generate a second set of summaries of each participant's views. Next, these summaries were scrutinized for patterns and/or categories, which were then checked against the data and modified accordingly. Finally, the profiles generated from the separate analyses of the questionnaires and corresponding interviews were compared. When discrepancies between the two profiles were evident, the data were reexamined to determine which profile best reflected the participant's views. Data analyses indicated that the Expert group's responses to the *VNOS–B* reflected current understandings at a rate nearly three times higher than those of the Novice

group (see Table 1). The results of this investigation lent strong support to the validity of the *VNOS–B*. Following are brief descriptions of Expert and Novice group responses to the *VNOS–B* items for each assessed aspect of NOS.

The Empirical Nature of Scientific Knowledge

All Expert group responses to *VNOS–B* #1 or #4 referred to the empirical NOS. Typical responses included descriptions of scientific knowledge as based on natural phenomena, evidence, data, information, and observation. Several Expert group participants attempted to describe science as a way of knowing by contrasting it with art or religion. These participants tended to focus on science's reliance on empirical data and reason, in contrast to art's focus on aesthetics and religion's reliance on faith and revealed truth. None of the Expert group participants spoke of science using observations or evidence to "prove" its conjectures. Rather, they tended to view empirical evidence as *supportive*, but not able to prove scientific claims in any absolute sense. Additionally, they did not see physical evidence as being the sole determinant in choosing between competing ideas or theories. Rather, they viewed scientific claims as being based on a mix of observational, personal, social, and cultural influences.

The Novice group participants also expressed a belief in an empirical basis for scientific knowledge. Unlike their Expert counterparts, however, many of the Novice group participants indicated that scientific knowledge is based *solely* on the evidence. In their view, the reliance on empirical evidence makes science an objective endeavor. Thus, they emphasized empiricism to the exclusion of the more personal attributes of interpretation, speculation, and opinion. Other Novice group participants spoke of science as a search for objective "truth." Indeed, 6 of the 9 (67%) Novice group participants emphasized the empirical nature of scientific claims to the exclusion of subjective factors, such as human bias and values.

Table 1

Comparison of Expert and Novice Group Responses to the *VNOS-B*

NOS Aspect	Expert group		Novice group	
Empirical Nature of Scientific Knowledge				
Observations used to make scientific claims	9	(100%)	8	(89%)
Science does not rely solely on empirical evidence	9	(100%)	3	(33%)
Supports, rather than *proves*, scientific claims	9	(100%)	3	(33%)
Inference and Theoretical Entities in Science				
Inferential nature of atomic models	9	(100%)	6	(67%)
Nature of Scientific Theories				
Theories change due to new evidence	9	(100%)	7	(78%)
Theories change due to new ways of looking at existing evidence	8	(89%)	4	(44%)
Explanatory power of scientific theories	8	(89%)	1	(11%)
Theories are well-substantiated	9	(100%)	0	(0%)
Theories provide a framework for current knowledge and future investigations	7	(78%)	1	(11%)
Scientific Theories vs. Laws				
Non-hierarchical relationship	9	(100%)	0	(0%)
Laws may change	9	(100%)	1	(11%)
Creativity in Science				
Creativity permeates scientific processes	9	(100%)	4	(44%)
No single scientific method	9	(100%)	0	(0%)
Subjectivity in Science				
Differences in data interpretation	9	(100%)	5	(56%)
Science is necessarily a mixture of objective and subjective components	9	(78%)	2	(22%)
Social and Cultural Influences				
Science as a culture within itself	8	(89%)	0	(0%)
Peer review limits subjectivity	3	(33%)	1	(11%)
Society as an influence on science	2	(22%)	2	(22%)
Overall	169	(89%)	64	(33%)

Inference and Theoretical Entities in Science

In their responses to *VNOS–B* #2, the Expert group participants' demonstrated an understanding of the inferential nature of scientific models. While all were confident that scientists understand much of what atoms are like, none appeared to believe that scientists "know" the structure of the atom in any absolute sense of the term. Rather, they used qualified language to describe scientists' certainty about atomic structure. The Expert group rejected the notion that scientists obtained their understandings of atoms through direct observations and ascribed a role for indirect evidence and/or inference in the construction of atomic models. By comparison, 67% of the Novice group participants held similar views, while the remaining 33% held the naïve view that atomic models have been developed through direct observation.

Nature of Scientific Theories

In response to *VNOS–B* #1, all nine Expert group participants indicated that scientific theories change and almost all ascribed theory change to new data and technologies, as well as to new insights, and social and cultural influences. Several participants described theories as robust, well-supported systems of explanation based on substantial evidence. Their understandings of scientific theories contrasted with the common vernacular sense of the word, in which "theory" is defined as a simple guess or unsubstantiated idea. Eight of the 9 participants cited the explanatory function of scientific theories in their responses to the question concerning the usefulness of learning scientific theories, and most of them (78%) argued that theories provide a framework for current knowledge and/or for future investigations.

In contrast, 7 of the Novice group participants (78%) stated that theories do change and cited a single reason for theory change, the accumulation of new evidence. During the follow-up interviews, 4 of the 7 also cited new ways of looking at existing evidence as a reason for theory

change. Unlike the Expert group participants, none of the Novice group members spoke of the well-substantiated nature of theories. Eighty-nine percent of this latter group participants did not seem to appreciate the role that theories play in generating research questions and guiding scientific inquiry.

Distinctions and Relationship Between Scientific Theories and Laws

All of the Expert group participants viewed scientific theories and laws as different kinds of knowledge; thus, the misconception of a hierarchical relationship between theories and laws was nonexistent. These participants viewed theories and laws as being distinct but equally valid forms of scientific knowledge. Only one participant viewed scientific laws as being certain in any absolute sense of the word. For the remaining Expert group members, tentativeness applied to laws just as it does for other forms of scientific knowledge.

Seven of the 9 Novice group participants (78%) explicitly stated the misconception that scientific theories become laws when proven, or when they have "passed" repeated testing. The other two respondents also believed laws were proven true and theories were tentative, either because not enough data are available, or because scientists are unable to design the necessary experiments or apparatus to adequately test theories. None of the Novice group participants contrasted the descriptive role of scientific laws with the explanatory nature of scientific theories, thus differing markedly from the majority of the Expert group respondents who viewed scientific theories as non-observable inferred explanations and scientific laws as descriptions of patterns or relationships among observable phenomena.

The Creative and Imaginative Nature of Scientific Knowledge

Expert group participant responses to *VNOS–B* #4 and #5 reflected the consistent belief

that creativity permeates the scientific process, from the earliest conceptions of a research question to the ingenuity required to set up and run an investigation to the ultimate interpretation of the results of the investigation. All group participants viewed creativity in science both in terms of resourcefulness in carrying out experiments and in inventiveness in interpreting data and coming up with inferences and theories. None of the Expert group participants adhered to the rigid view of a single scientific method, but allowed for various approaches to answering various research questions.

By comparison, Novice group responses to these *VNOS–B* items indicated that only four (44%) viewed creativity and imagination as integral to science. Novice group participants' views further contrasted with those of the Expert group in that they all expressed belief in a single scientific method. For these participants, most creativity in science occurs during conjecturing and before the scientific method is employed. After that, the scientific method is used to determine whether the scientist's conjectures were "correct."

The Subjective Nature of Scientific Knowledge

In responding to the astronomical controversy presented in *VNOS–B* #7, Expert group participants focused on differences in interpreting the data due to the scientists' different backgrounds and training. In doing so, they ascribed a role for subjectivity in the construction of scientific knowledge, whereby different interpretations can result from astronomers working within various frameworks, which could vary with the scientists' educational backgrounds, training, philosophical perspectives, theoretical commitments, personal experiences, and beliefs. By comparison, the Novice group participants tended to focus on inadequacies or differences in the data the astronomers were using. Responses like this reflect a more objective view of science. About 56% of the Novice group participants noted that subjectivity is a part of science,

especially in regard to interpreting data. However, these participants believed that subjectivity, while a factor of human nature, is to be avoided in science. Only two of the Novice group participants appeared to have informed views of the theory-laden nature of observations, investigations, and data interpretation.

Social and Cultural Influences on Scientific Knowledge

In their responses to *VNOS–B* #4 and #6, the Expert group participants described two types of cultural influences involved in the development of scientific knowledge. The first relates to the culture of science itself and includes such factors as peer review. Eight of the 9 Expert group participants (89%) discussed a culture or community within science that establishes rules of practice and evidence, essentially acting as judge for what is acceptable in science. These rules play a crucial role in limiting subjectivity through the application of peer review and group consensus. The second type relates to the influence of societal factors, such as politics, economics, and religion, on science. Two Expert group participants (22%) noted that the social milieu in which science is conducted influence the kind of science that is done. Such influence is mediated by various factors, including economic and political contexts, funding for science, and gender and racial issues. In comparison, only three Novice group participants (33%) made any reference to social or cultural influences on the development of scientific knowledge.

VNOS Form–C

Abd-El-Khalick (1998) further modified and expanded the *VNOS–B* by adopting item 3, modifying items 1, 2, 5, and 7, and adding five new items. A panel of experts examined these ten items to establish their face and content validity. The panel comprised five university professors: three science educators, a historian of science, and a scientist. The panel had some comments and

suggestions for improvement and the ten items were modified accordingly. In addition to assessing respondents' views of the NOS aspects targeted by the *VNOS–B*, the *VNOS–C* (see Figure 2) also aimed to assess views of the social and cultural embeddedness of science and the existence of a universal scientific method. Additionally, Abd-El-Khalick developed an interview protocol to further probe participants' views on relevant NOS issues. These questions were asked during follow-up interviews either as individual questions or sets of interrelated questions. Certain questions or sets of questions were asked following interviewees' explication of their responses to a certain item on the *VNOS–C*. Alternatively, other questions or sets of questions were *only* asked when interviewees expressed certain ideas regarding NOS. Coupled with the *VNOS–C* responses, these interview questions allowed assessing respondents' views of the general aim and structure of scientific experiments, the logic of theory and hypothesis testing, and the validity of observationally-based (as compared to experimentally-based) scientific theories and disciplines.

VNOS–C was administered to college undergraduates and graduates, and preservice secondary science teachers (Abd-El-Khalick, 1998; Abd-El-Khalick & Lederman, 2000b). Many participants noted, often in response to *VNOS–C* #1, that science is characterized by "the" scientific method or other sets of logical and orderly steps. During the follow-up interviews these participants were asked, "Do all scientists use a specific method, in terms of a certain stepwise procedure, when they do science? Can you elaborate?" In their response to *VNOS–C* #2, many participants defined scientific experiments very broadly as "procedures used to answer scientific questions." In the attempt to clarify such responses interviewees were asked, "Are you thinking of an experiment in the sense of manipulating variables or are you thinking of more general procedures? Can you elaborate?"

Figure 2. Views of Nature of Science Questionnaire (Form C)

VNOS–Form C

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge **require** experiments?
   - If yes, explain why. Give an example to defend your position.
   - If no, explain why. Give an example to defend your position.

4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
   - If you believe that scientific theories do not change, explain why. Defend your answer with examples.
   - If you believe that scientific theories do change: (a) Explain why theories change? (b) Explain why we bother to learn scientific theories? Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence **do you think** scientists used to determine what an atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and use the **same set of data** to derive their conclusions?

(figure continues)

Figure 2. *(continued)*

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
   - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
   - If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
    - If yes, then at which stages of the investigations you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
    - If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Also, mostly in response to the first and second items, many participants noted that scientific knowledge is "proven" knowledge or that scientific experiments aim to "prove" or "disprove" hypotheses or theories. Interviewees were asked, "How would you 'prove' a theory or hypothesis?" A typical response was that scientific claims are "proven" by collecting evidence and/or doing experiments. Interviewees were then asked, "How much evidence or how many experiments does it take to 'prove' a scientific claim?" or "How much evidence and/or how many experiments are 'enough' to prove a scientific claim?"

In response to *VNOS–C* #3, some participants noted that developing scientific knowledge necessarily requires *manipulative* experiments. In an attempt to elucidate how this view relates to the case of "observational" sciences, interviewees were then asked a set of questions. The first question was, "Let's consider a science like astronomy (or anatomy). Can we (or do we) do manipulative experiments in astronomy (or anatomy)?" If interviewees answered in the positive

they were asked to explicate their answers and provide examples. This served to further probe interviewees' conceptions of scientific experiments. However, if they answered in the negative, the interviewees were then asked, "But we still consider astronomy (or anatomy) a science. What are your ideas about that?"

Other follow-up questions aimed to assess the depth of participants' understanding of the theory-laden nature of science and the role that scientific theories and theoretical expectations play in guiding scientific research. Two of these questions followed interviewees' explication of their responses to *VNOS–C* #2 on scientific experiments. The questions were, "When scientists perform 'manipulative' experiments they hold certain variables constant and vary others. Do scientists usually have an idea about the outcome of their experiments?" If interviewees agreed, they were then asked, "Some claim that such expectations would bias the results of an experiment. What do you think?" Two other questions followed the fourth item that related to scientific theories. On noting that scientific theories change in their responses to the questionnaire, interviewees were asked, "The history of science is full with examples of scientific theories that have been discarded or greatly changed. The life spans of scientific theories, if you will, vary greatly, but theories seem to change at one point or another. And there is no reason to believe that the scientific theories we have today will not change in the future. Why do we bother learn about these theories? Why do we invest time and energy to grasp these theories?" The other question was, "Which comes first when scientists conduct scientific investigations theory or observation?"

A question that followed interviewees' discussion of *VNOS–C* #5 was "In terms of status and significance as products of science, would you rank scientific theories and laws? And if you choose to rank them, how would you rank them?" Two other questions followed when

participants' responses to the sixth item on the structure of the atom were not informative regarding their views of the role of inference and creativity in science. The first question was "Have we ever 'seen' an atom?" If they responded in the negative, interviewees were then asked, "So, where do scientists come up with this elaborate structure of the atom?" Those interviewees who thought that scientists have actually "seen" an atom were asked to elaborate on their answers. Similarly, *VNOS–C* #7 aimed to assess participants' understandings of the role of inference and creativity in science. On noting that scientists were very certain about the notion of species, interviewees were asked, "There are certain species of wolfs and dogs that are known to interbreed and produce fertile offspring. How does this fit into the notion of species, knowing that the aforementioned species are 'different' species and have been given different names?"

To assess whether participants thought of creativity and imagination in scientific investigation more as "resourcefulness" and "skillfulness" or as "invention" of explanations, they were asked, "Creativity and imagination also have the connotation of creating something from the mind. Do you think creativity and imagination play a part in science in that sense as well?" Finally, in response to the item related to the dinosaur extinction controversy, many interviewees thought that the controversy was unjustified given that the evidence supports both hypotheses. In that case, the interviewees were asked, "This is very reasonable. It is very reasonable to say that the data is scarce and that the available evidence supports both hypotheses equally well. However, scientists in the different groups are very adamant about their own position and they publish very pointed papers in this regard. Why is that?"

In addition to undergraduate and graduate college students (Abd-El-Khalick, 1998), the *VNOS–C* was also administered to preservice elementary teachers (Abd-El-Khalick, 2000), and preservice and inservice secondary science teachers (Abd-El-Khalick, 1998; Abd-El-Khalick &

Lederman, 2000b; Lederman, Schwartz, Abd-El-Khalick, & Bell, in press; Schwartz & Lederman, in press; Schwartz, Lederman, & Crawford, 2000). Abd-El-Khalick (1998, 2000) established the content validity of the *VNOS–C* by comparing and contrasting participants' NOS profiles that were generated from separate analyses of the questionnaires and corresponding interview-transcripts. In these studies, the questionnaires of interviewed participants were first analyzed to generate a profile of these participants' NOS views. Next, similar analyses were conducted using the same participants' interview transcripts. The independently generated profiles were systematically compared and contrasted. Comparisons indicated that interpretations of participants' NOS views as elucidated in the *VNOS–C* were congruent to those expressed by participants during individual interviews. Finally, it is important to note that all versions of the *VNOS* yield consistent findings in areas of overlap.

Collecting and Analyzing *VNOS* Data: Important Logistical and Conceptual Issues

Administering the *VNOS*

It is preferable to administer the *VNOS* under controlled conditions (e.g., in class under supervision). However, given the open-ended nature of the *VNOS* items, it is important not to set time limits. Our participants typically spent 35–45 minutes to complete the *VNOS–B* and 45-60 minutes to complete the *VNOS–C*. Each *VNOS* item is printed on a single page to provide respondents with ample space to write their answers. Respondents should be encouraged to write as much as they can in response to any one item, make sure to address all sub-sections of an item, and provide supportive or illustrative examples where asked to. The *VNOS* should not be used for summative assessment purposes in any manner since such use might impinge on

respondents' answers. Respondents' should be reminded that there are no "right" or "wrong" answers to any item and that the intention is to elicit their views on some issues related to NOS.

Following the administration of the *VNOS*, a reasonable sample of respondents should be individually interviewed. During these interviews, respondents are provided their *VNOS* questionnaires and asked to explain and justify their responses. Follow-up and probing questions could be used to clarify ambiguities, assess meanings that respondents ascribe to key terms and phrases, and explore respondents' lines of thinking. For researchers using the *VNOS* for the first time, we recommend interviewing all or a large majority of respondents. With repeated use, researchers should develop expertise in interpreting *VNOS* responses. Such expertise becomes evident when researchers obtain high degrees of correspondence between their inferences regarding respondents' NOS views as derived from *VNOS* responses and the views elucidated by those respondents during individual interviews. At this point, researchers could interview sub-samples of respondents. As noted earlier, we now find interviewing 15-20% of our respondents sufficient to gauge subtleties of meaning associated with a certain group of respondents or a certain context. Interviewees could be chosen either randomly or purposively depending on the purpose of administering the instrument.

Analyzing Responses to the *VNOS*

The first step in analyzing *VNOS* data is to reaffirm the validity of the questionnaire in the context in which it is used and flesh out the subtleties of meanings that respondents in that context ascribe to key terms and phrases. This step can be achieved by systematically comparing and contrasting profiles of respondents' NOS views that are generated by the separate analyses of interviewees' questionnaires and interview transcripts. If a high degree of congruence between the separately generated profiles is obtained—or once such a high degree is established by

modifying the researchers' interpretations of *VNOS* responses to accommodate interview data, all questionnaires data could be analyzed.

When several researchers are involved in analyzing *VNOS* responses, it is crucial to establish inter-rater agreement or reliability. Such agreement could be established by having all researchers independently analyze the same subset of data and then compare and contrast their analyses. Discrepancies could be resolved by further consultation of the data (especially interview data) or consensus. Analyses of all questionnaire and interview data should only proceed after establishing such reliability (see Abd-El-Khalick et al., 1998).

Analysis of responses to *VNOS* items does not assume a restrictive one-to-one correspondence between an item on the questionnaire and a target NOS aspect. To be sure, certain items target one NOS aspect to a larger extent than others. For instance, *VNOS–B* #1 and #5 and *VNOS–C* #4 and #10 largely target respondents' views of the tentative and creative NOS respectively. However, views of the target NOS aspects could be explicated in response to other items on the questionnaires. For instance, understandings of the tentative and creative aspects of NOS could be expressed in response to *VNOS–B* #2 and #3 and *VNOS–C* #1, #5, #6, and #7.

This approach to the analysis has two major advantages. First, it is consistent with our belief that NOS understandings should not be construed in the narrow sense of specific desired responses to cues set by specific questions. Rather, participants could demonstrate their NOS understandings in several contexts. Second, this approach allows to check for meaningful understandings of a NOS aspect versus superficial reiteration of key terms by checking for consistency, or lack thereof, in respondents' answers across *VNOS* items. For example, in response to *VNOS–C* #4, respondents might indicate that they believe that scientific theories could change in the future without providing examples. This might indicate that these

respondents endorse a tentative view of NOS. However, if the same respondents explicitly note in response to *VNOS–C* #5 that "theories become laws when they are proven true" or in response to *VNOS–C* #6 and #7 that scientists were certain about atomic structure and the notion of species, then one could hardly infer that they have internalized an understanding of the tentativeness of scientific knowledge. By the same token, if respondents demonstrate understandings of the creative and imaginative NOS in their responses to, say, *VNOS–C* #6, #7, #8 and #10, then it would be safe to infer that they have developed solid understandings of this NOS aspect. To be sure, if respondents explicate informed views of a target NOS aspect in any one item and there were no inconsistencies or other disconfirming evidence in their responses to other *VNOS* items regarding this aspect, then they should be judged to have informed views.

Moreover, it is important to note that "low inference" is desired throughout the analysis. This is not to say that respondents' answers should be taken literally. Indeed, data from follow-up interviews often suggest alternative ways of interpreting responses, which on initial examination seem to strongly suggest certain NOS views. For example, in our studies, many participants often used the terms "prove" and "proof," which could be taken to mean that they harbored an absolutist view of scientific knowledge. However, further probing during the interviews indicated that many of those participants used the term "proof" to refer to "evidence" and not to the more robust meaning of the word "proof," which indicates knowing with certainty. Care should be exercised in order not to load respondents' words and phrases with high-inference meanings or impose on respondents' views consistent structures unless interview data suggest otherwise. Indeed, in many cases we found that respondents' views were fluid, fragmented, and compartmentalized. For instance, some of our participants indicated in their responses to *VNOS–B* #5 that scientists use imagination and creativity in their work. These same

participants, however, indicated elsewhere in their questionnaires that scientists use "The Scientific Method." When asked during interviews to address these seemingly contradictory views, it became evident that those participants lacked an overarching consistent framework for their NOS views. This latter finding, it should be noted, was always masked when standardized convergent instruments were used to assess learners' NOS views. Irrespective of whether learners actually did or did not possess a coherent framework for NOS, standardized and convergent instruments, by virtue of their design, gave the impression that those respondents ascribed to consistent philosophical stances.

Most *VNOS* items ask respondents to provide examples to support their views. These examples should be carefully examined and factored in when assessing respondents' NOS views. For instance, some of our participants provided "Murphy's law" and "CH_3 is a methyl group" as examples of scientific laws. Others provided the (historically inaccurate) example of the shift from a "flat to a rounded conception of the shape of the earth" as an example of theory change. Such examples help to contextualize participants' conceptions of key concepts and shed light on some of their naïve (or informed) ideas.

Finally, as a rule of thumb, interview data should be given priority when respondents' views as explicated in the questionnaires are inconsistent with views they expressed during individual interviews. This latter use of interview data, however, assumes "good" interviewing practices, such as observing extended-wait time, avoiding directive cues, testing initial hypotheses about an interviewee's conceptions through non-directive follow-up or probing questions.

Illustrative Examples of Responses to the *VNOS*

Tables 2 and 3 present illustrative examples of responses to the *VNOS–B* and *VNOS–C*

items and interview questions respectively. These examples are verbatim quotes selected from *VNOS* responses and interview transcripts of participant undergraduate and graduate college students, and preservice and inservice elementary and secondary science teachers in our various studies. The examples serve to illustrate our respondents' views of several important aspects of NOS, which are presented along continua from more naïve toward more informed views. Needless to say, views of the target NOS aspects are necessarily interrelated and one quote that is used to illustrate naïve (or informed) views of one NOS aspect could as well be used to illustrate naïve (or informed) views of another aspect. The assignment of the quotes is, in that sense, somewhat arbitrary and only intended to make the presentation of respondents' NOS views manageable.

It is important to note that the examples presented in Tables 2 and 3 are shorthand illustrations of the sort of rich and intensive data generated by the use of the *VNOS* and associated interviews. Nonetheless, even with these examples, it is not difficult to discern that the *VNOS* items generate responses that clearly discriminate naïve from informed NOS views and, more importantly, provide insight into respondents' thinking about the target NOS aspects. Additionally, it is not difficult to see how the sort of responses provided by one or several respondents could be used to construct intensive individual or aggregate profiles of NOS views respectively. The kind of data generated by using the various *VNOS* versions clearly surpasses the cumulative numerical data generated by utilizing standardized convergent paper-and-pencil NOS assessment instruments in several respects. First, *VNOS* data explicate what respondents *actually* think in terms of NOS and the reasons underlying their thinking. Respondents' reasoning could be examined further during follow-up interviews. Second, given the non-categorical and rich nature of the *VNOS* responses and their sensitivity to subtle differences in

Table 2

Illustrative Examples of Responses to *VNOS–B* Items

NOS aspect	More naïve views	⇔	More informed views
Empirical NOS	Science is concerned with facts. We use observed facts to prove that the theories are true. (Item #6)	⇔	Scientists collect data to support their interpretation of the world. Artists just show their interpretation of the world. (Item # 6)
Tentative NOS	Theories more develop than change. Scientists keep on adding to our theories so that they become better. (Item #1) If you get the same result over and over and over, then you become sure that your theory is a proven law, a fact. (Item #3)	⇔	Everything in science is subject to change with new evidence and interpretation of that evidence. We are never 100% sure about anything because . . . negative evidence will call a theory or law into question, and possibly cause a modification. (Item #1)
Creative and imaginative NOS	A scientist only uses imagination in collecting data . . . But there is no creativity after data collection because the scientist has to be objective. (Item #5)	⇔	Both science and art are created by humans' minds. Both reach their fullest expression only when the scientist or artist shares his/her creation with other human beings. However, science is based on evidence, whereas art is not. (Item #4)
"The Scientific Method"	Science deals with using an exact method so we can duplicate our results. That way we know we have the right answer. (Item #4)	⇔	There is no one method of doing science. In developing their methods, scientists use imagination and creativity. (Item #5)
Inferential nature of scientific constructs	Scientists can see atoms with high-powered microscopes. They are very certain of the structure of atoms. You have to see something to be sure of it. (Item #2)	⇔	Evidence is indirect and relates to things that we don't see directly. You can't answer . . . whether scientists know what the atom looks like, because it is more of a construct. (Item #2)
Relation between theories and laws	Laws started as theories and eventually became laws after repeated and proven demonstration. (Item #3)	⇔	A scientific law describes something that happens in nature. A theory is an attempt by scientists to explain why nature is the way it is. (Item #3)
Subjective (theory- laden) NOS	Scientists are very objective because they have a set of procedures they use to solve their problems. Artists are more subjective, putting themselves into their work. (Item #4)	⇔	Scientists are human. They learn and think differently, just like all people do. They interpret the same data sets differently because of the way they learn and think, and because of their prior knowledge. (Item #7)

Table 3

Illustrative Examples of Responses to *VNOS–C* Items and Interview Questions

NOS aspect	More naïve views	⇔	More informed views
Empirical NOS	Science is something that is straightforward and isn't a field of study that allows a lot of opinions, personal bias, or individual views–it is fact based. (Item #1) I believe science is different . . . because it uses concrete facts that have been proven/ are observable/ can be repeated and seen by someone else to get a right or wrong answer. (Item #1)	⇔	Much of the development of scientific knowledge depends on observation . . . [But] I think what we observe is a function of convention. I don't believe that the goal of science is (or should be) the accumulation of observable facts. Rather, I think that . . . science involves abstraction, one step of abstraction after another. (Interview, follow-up on item #1)
"The Scientific Method"	Science has a particular method of going about things, the scientific method. (Item #1) The key to the difference between science and other inquires, is that science follows a rigid set of rules. (Item #1)	⇔	When you are in sixth grade you learn that here is the scientific method and the first thing you do this, and the second thing you do that and so on so forth. That's how we may say we do science, but there is a difference between the way we say we do science and the way that we actually do science. (Interview, follow-up on item #1)
General structure and aim of experiments	An experiment is a sequence of steps performed in order to prove a proposed theory. (Item #2) Experiment is everything that involves the act of collecting data and not necessarily manipulation. (Interview, follow-up on item #2)	⇔	An experiment is a controlled way to test and manipulate the objects of interest while keeping all other factors the same . . . the results . . . will lead the scientist to believe his/her theory has or doesn't have validity. (Item #2) An experiment cannot prove a theory or a hypothesis. It just discredits or adds validity to them. (Item #2)
Role of prior expectations in experiments	You usually have some sort of idea about the outcome. But I think that to have a scientific and valid experiment you should not have any bias or ideas in advance. (Interview, follow-up on item #2)	⇔	In order to organize an experiment you need to know what is going to come out of it or it wouldn't really be a test method. I don't know how you would organize a test . . . if you don't have a general idea about what you are looking for. (Interview, follow-up on item #2)
Validity of observationally-based theories and disciplines	Science would not exist without scientific procedure which is solely based on experiments . . . The development of knowledge can only be attained through precise experiments. (Item #3)	⇔	Experiments are not always crucial . . . [For] example . . . Darwin's theory of evolution . . . cannot be directly tested experimentally. Yet, because of observed data, such as fossils and rock formations, it has become virtually the lynchpin of modern biology. (Item #3)

(table continues)

Table 3. *(continued)*

NOS aspect	More naïve views	⇔	More informed views
Scientific theories			
Nature of	Theories are just that, one person's view or thought on what occurred. (Item #4)	⇔	In the vocabulary of a scientist the word theory is used differently than in the general population. It does not mean someone's idea that can't be proven. It is a concept that has considerable evidence behind it and has endured the attempts to disprove it. (Item #4)
	A theory is an untested idea, or an idea that is undergoing additional tests, Generally it hasn't been proved to the satisfaction of the scientific community. (Item #4)		
Functions of	We learn scientific theories just so that scientists don't start all over from the beginning . . . they just can add to the old ideas. (Item #4)	⇔	Theories set a framework of general explanation upon which specific hypotheses are developed. Theories, even if temporary, also advance the pool of knowledge by stimulating hypotheses and research, which may support the current theory or lead to new theories. (Item #4)
Logic of testing	Many theories can't be completely tested, e.g. the theory of evolution can't be tested unless you create your own world and then live for millions of years. (Item #5)	⇔	Most theories have things we cannot observe. So, we deduce consequences from them that could be tested. This indirect evidence allows us to see if the theory is valid. (Interview, follow-up to item #5)
Difference and relationship between theories and laws	A scientific law is a theory that has been . . . proven again and again over time to be true. (Item #5)	⇔	A scientific law describes quantitative relationships between phenomena such as universal attraction between objects. Scientific theories are made of concepts that are in accordance with common observation or go beyond and propose new explanatory models for the world. (Item #5)
	A scientific law is somewhat set in stone, proven to be true . . . A scientific theory is apt to change and be proven false at any time. (Item #5)		
Tentative NOS	Compared to philosophy and religion . . . science demands definitive answers with right & wrong answers. (Item #1)	⇔	[Science] strives to ask questions and is fueled by the desire to answer such questions and the acceptance that science is not absolute. (Item #1)
	I believe that most of the time they [theories] do *not* change because they are basic theories that will only accept *alterations* [italics in original]. (Item #4)		Theories do change because of new data and because of changing ideas and societies' view of the world changes. (item #4)
	A law has been tested and cannot be changed. (Item #5)		Laws like theories are tentative. (Item #5)

(table continues)

Table 3. *(continued)*

NOS aspect	More naïve views	⇔	More informed views
Creative and imaginative NOS	I don't think scientific investigation is best characterized by creativity or imagination. I think a composer can be creative, a novelist can be imaginative, etc. . . . Scientific investigations are often tedious and repetitive, with the sole purpose of generating new data on the basis of previous data. (Item # 10) You need to sort take away your mind after you collect the data . . . You don't want to be creative when you interpret data. (Interview, follow-up on Item 10)	⇔	Logic plays a large role in the scientific process, but imagination and creativity are essential for the formulation of novel ideas . . . to explain why the results were observed. (Item #10) Scientists use creativity and imagination during their investigations . . . to come up with plausible explanations for the data and possible other questions to pursue answers to. (Item #10)
Inference and theoretical entities	I think scientists are pretty sure about the structure of the atom. The evidence they use is microscopic pictures of the actual atoms. (Item #6)	⇔	Models of the structure of the atom are frequently being updated. Current theories . . . explain observed phenomena with a fairly high degree of certainty, but only indirect evidence can be used to formulate such theories. (Item #6)
	There is . . . scientific certainty [about the concept of species]. While in the early days it was probably a matter of trial-and-error . . . nowadays genetic testing makes it possible to define a species precisely. (Item #7)	⇔	Species is . . . a completely human creation. It is a convenient framework for categorizing things, animals and plants . . . It is a good system but I think the more they learn the more they realize that . . . we cannot draw the line between species or sub-species or sub-populations of a sub-species. (Interview, follow-up to item #7)
Subjective or theory-laden NOS	[Scientists reach different conclusions] because the scientists were not around when the dinosaurs became extinct, so no one witnessed what happened . . . I think the only way to give a satisfactory answer to the extinction of the dinosaurs is to go back in time to witness what happened. (Item #8) This [controversy] might be an instance where, because of lack of real evidence, scientists *did* [italics in original] use their creativity and imagination. (Item #8)	⇔	Both conclusions are possible because they may be different interpretations of the same data. Different scientists may come up with different explanations based on their own education and background or what they feel are inconsistencies in others ideas. (Item #8) Scientists are human and when the geophysicists get together and examine the evidence they are doing it from a certain perspective . . . and tend to emphasize the geophysics data. The paleontologists come along, see the same data and interpret it from their perspective. Scientists, people of a certain ilk, see the world through rose tinted glasses. (Item #8)

(table continues)

Table 3. (*continued*)

NOS aspect	More naïve views	⇔	More informed views
Social and cultural embeddedness of science	Science is about the facts and could not be influenced by cultures and society. Atoms are atoms here in the US and are still atoms in Russia. (Item #9)		Of course culture influence the ideas in science. It was more than a 100 years after Copernicus that his ideas were considered because religious beliefs are the church sort of favored the geocentric model. (Item #9)
	Well, the society can sometimes not fund some scientific research. So, in that sense it influences science. But scientific knowledge is universal and does not change from one place to another. (Interview, follow-up on item #9)		All factors in society and the culture influence the acceptance of scientific ideas . . . Like the theory of evolution was not accepted in France and totally endorsed in Germany for basically national, social, and also cultural elements. (Item #9)

terms of NOS views, the *VNOS* allows for meaningful assessments of changes—no matter how small, in learners' NOS views as a result of various instructional interventions, and an assessment of the interaction between learners' NOS views and the nature of the specific instructional activities undertaken in these interventions from diagnostic and cognitive perspectives. This latter assessment is surely very informative in terms of modifying and enhancing the effectiveness of such interventions.

Conclusion and Implications

Establishing the validity of an instrument is an on-going process. In fact, it is incorrect to speak of validity as ever being "established" in the once-and-for-all sense of the word. Rather, at best, we can only provide evidence of an instrument's efficacy in measuring what it is designed to measure. Due to its open-ended nature, the *VNOS* differs from typical paper-and-pencils instruments. While face and content validity of the various versions of the instrument have been determined repeatedly, its principle source of validity evidence stems from the follow-up

interviews. During these interviews, it is possible to directly check respondents' understandings of each item, as well as the researchers' interpretation of these responses. In our various studies, the three forms of the *VNOS* were administered to about 2000 high school students, college undergraduates and graduates, and preservice and inservice elementary and secondary science teachers across four continents. This was coupled with about 500 individual interviews. The results of these studies and follow-up interviews support a high confidence level in the validity of the *VNOS* for a wide variety of respondents. We believe that the *VNOS* items and interview protocol may be applied with confidence when assessing understandings of NOS.

The most significant question to be asked of the present instrument would be: Isn't the *VNOS* just another paper-and-pencil NOS instrument? The response to this question is by no means simple. The *VNOS* is different in underlying assumptions and form from standardized and convergent instruments. It was developed with an interpretive stance in mind, and aims to elucidate learners' NOS views and generate profiles of the meanings they ascribe to various NOS aspects for the purpose of informing the teaching and learning of NOS rather than for labeling learners' views as "adequate" or "inadequate" or sum their NOS understandings into less-than-informative numerical scores. However, even though the open-ended nature of the *VNOS* items do ameliorate some of the concerns associated with the use of standardized convergent paper-and-pencil instruments, the *VNOS* could be easily "abused" if its interpretive stance and qualitative interviewing component were overlooked or undermined. As such, the importance of coupling the use of the *VNOS* with individual in-depth follow-up interviews with all or a reasonable sample of respondents cannot be overemphasized.

Despite these concerns, we decided to "release" the *VNOS* in light of some recent and disconcerting calls within the science education community to develop other forced-choice

standardized and convergent NOS instruments (e.g., Good et al., 2000) designed especially for mass administrations to large samples. These calls have ignored the problematic nature of these instruments, recent general trends in education, such as the concern with learners' own conceptions of subject matter, and years of intensive research that has shown the inadequacies of such assessment approaches in informing research on teaching and learning in general, and NOS in particular. Indeed, these calls ignore all that we have learned from research on teaching and learning about NOS over the past 30 years. The present state of this line of research necessitates a focus on individual classroom interventions aimed at enhancing learners' NOS views, rather than on mass assessments aimed to describe or evaluate students' beliefs. Thus, we found it useful to present the *VNOS* for general use with as much qualification as we could with regard to its underlying assumptions and methodological considerations. We hope that the *VNOS* would lead the way toward more valid and meaningful assessment of students' and teachers' NOS views.

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THINKING REFLECTIVELY RATHER THAN REFLEXIVELY: A THEORETICAL FRAMEWORK FOR PORTFOLIO DEVELOPMENT IN TEACHER EDUCATION

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During the past decade, a substantial literature has accumulated that describes the use of portfolios in teacher education (Anderson & DeMeulle, 1998; Bartell, Kaye, & Morin, 1998a, 1998b; Berg & Curry, 1997; Cerbin, 1995; Chance & Rakes, 1994; Dutt-Donter & Gilman, 1998; Erchick, Kos, Andersen, Warner, & Kent, 2001; Fleming, 1999; Freidus, 1998, 2000; Georgi & Crowe, 1998; Grant & Huebner, 1998; Guillaume & Yopp, 1995; Johnson, 1999; Lyons, 1998; McKinney, 1998; Montgomery, 1997; Piper, 2000; Rakow, 1999; Shannon, 1994; Snyder, Lippincott, & Bower, 1998; Stone, 1998; Wile, 1999; Wolf & Dietz, 1998; Wolf, Whinery, & Hagerty, 1995). Though most commonly used to represent the range of a practitioner's professional expertise, portfolios also have been used within methods courses in specific content areas, including reading and language arts (Athanases, 1994; Wagner, Brock, & Agnew, 1994), science (Barton & Collins, 1993), mathematics (Cole, Ramey, Tomlin, Ryan, Swann, & Sutton 2000), social studies (Ross, 1996), music (Rogers, 1995), and art (Emme, 1996). Though these approaches differ in purpose and method, they share in common an emphasis on the teacher's reflective thought on her practice, a view shared by Schön (1983, 1987) and other theorists in the field. It is presumed that through this self-reflection, teachers examine their assumptions, personal theories, and behaviors as practitioners. Though these results of reflection have been described in detail, there has been little attempt to characterize the cognitive nature of the reflection process itself. The present paper links the research in portfolio use in teacher education

with our own empirical research in metacognition, thereby providing a theoretical framework for portfolio development that fosters reflective thought.

<u>The Acquisition of Teaching Strategies: Performance- and Meta-level Thought</u>

A core goal in teacher preparation is the acquisition of strategies in instruction, management, and other areas. Traditional views of strategy development in cognitive psychology have used a stage approach that posits that older, less effective strategies are supplanted by newer, more effective ones. For example, the strategies used by beginning teachers often do not correspond to best practices, due to deficiencies in their training, lack of experience, teaching situation, or other reasons. In the stage view, ongoing professional development of teachers involves training in new teaching techniques to improve practice. During the process, teachers abandon older techniques that are less effective.

However, research in cognitive psychology has found that older strategies are not simply replaced by newer ones. Instead, new strategies co-exist alongside older strategies, despite the relative ineffectiveness of the older strategies (Kuhn & Phelps, 1982). Thus, after professional development, teachers do not simply "upgrade" to newer teaching strategies but instead have an array of new and old strategies of differing effectiveness and utility to draw upon.

If teachers have a collection of strategies (both best practice and otherwise) that could be applied in a given situation, how do teachers decide which strategies to employ in a given situation? Professional development commonly emphasizes details techniques and tips for carrying out a teaching method (the "how to" of the strategy), a level of understanding characterized by Kuhn (in press) as performance-level operation. Receiving less attention in professional development is imparting an understanding of the pros and cons of the teaching

method, appropriate and inappropriate circumstances for its application, and the theory behind the practice (the "why" of the strategy). In contrast to performance-level operation, this meta-level operation (Kuhn, in press) goes beyond competent performance of the teaching technique (i.e., thinking with the strategy) and involves thinking about the strategy itself and considering the circumstances and context surrounding its performance.

This meta-level knowledge comes in various forms. The term metacognitive ("thinking about thinking") has been used as an umbrella term in the cognitive psychology literature, but its many (and sometimes contradictory) uses have caused theorists to divide the meta-level realm into parts. For example, metaconceptual knowledge (Andersen, 1998) involves not just understanding a concept but rather being able to think about the concept, its relative ability to explain a phenomenon compared to other concepts, the evidence supporting or refuting the concept, etc.

Meta-level knowledge is key for the effective selection of an appropriate technique from the teacher's array. In addition to performance-level knowledge about how to carry out a strategy, teachers possess meta-level knowledge about why to invoke one strategy over another. This metastrategic knowledge (Kuhn, Garcia-Mila, Zohar, & Andersen, 1995) includes information about the strengths and weaknesses of each strategy, the effort involved in implementing the strategy, and other factors.

One lesson from research into cognitive development has been that the acquisition of a new strategy is not particularly difficult in many cases. Instead, the challenge in cognitive development (including strategies of teaching) lies the development of the metastrategic knowledge associated with the new strategy, thereby allowing the learner to employ the most

appropriate strategy from one's repertoire. Expert teachers are distinguished from novices by their meta-level knowledge of the field (particularly metastrategic knowledge). In addition to the performance level skills typically presented in professional development experiences, teachers need experiences to foster the growth of the metastrategic knowledge associated with those skills. It is through reflection on one's practice that metastrategic and other meta-level knowledge is developed (Andersen, 2000).

Using Portfolios to Foster Meta-level Thought

Portfolios serve to foster reflection on performance-level and meta-level knowledge in three ways. First, the realities of classroom teaching are such that teachers are generally "thinking reflexively rather than reflectively" (Andersen, 2000), reacting to the concerns of the moment without considering why they are reacting in that way. The preparation of the portfolio provides a reason for teachers to step out of the reflexive mode and take the opportunity to reflect on their practice.

Second, in contrast to the implicit thinking inherent in individual reflection, the preparation of the portfolio requires the teacher to make her reflection explicit. This writing process requires a level of consolidation of thinking (in this case, both performance- and meta-level thinking) that is rarely reached during the musings over one's own thinking.

Third, because self-reflection is by definition an internal mental process. As a result, it is difficult to share one's self-reflections with others in a collaborative manner or even to critique one's own process of reflection. The artifacts and written elements used in the portfolio provide an externalized form of the internal reflective process, allowing for easier commentary by others and self-examination of one's own reflecting.

Conclusion

Though many researchers have found success in using portfolios to improve professional practice, this success has not been universal. The present paper posits that the effectiveness of the portfolio process may be improved by encouraging reflection not only on performance-level understanding of teaching but also on the meta-level (particularly metastrategic) understanding that is needed for expert use of new strategies. The research in teacher portfolio use suggests that those who are promoting the use of portfolios are similarly engaging in performance-level thinking about the portfolio process, focusing on the process of how to reflect without sufficient meta-level thinking about the nature of the reflective process itself. It is hoped that the argument presented here serves as a metastrategic guide to those promoting portfolio use in teacher education.

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PROSPECTIVE ELEMENTARY TEACHERS' USE OF AN ONLINE COMMUNICATIVE TOOL: IMPLICATIONS FOR THE USE OF TECHNOLOGY IN SCIENCE TEACHING PREPARATION

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As witnessed on a daily basis, technology has become increasingly interactive and distributed such that learners of the 1990s have available the means to participate in incredibly complex networks of information and resources (Harasim, 1993). Based on Bonk, Malikowski, Angeli, and East (1998) various technologies can support activities for collaborative products and joint knowledge building, expert mentoring, peer commenting and review, and the publication of one's work.

While there are many studies established about the web-based collaboration (e.g. Audet, Hickman & Dobrynina, 1996; Copeland, 1987; Hmelo & Guzdial, 1997), we know very little from empirical research about the nature of the electronic discourses and discussions that are developed during the collaboration. There are many questions to be answered such as 'When do participants talk to each other?', 'How often do they talk to each other?', 'Why do they talk to each other?', 'What kinds of patterns characterize the discussion?', 'What is the nature of the discourse?' (Lee & Songer, 1998).

The purpose of this study, therefore, was to examine the discourse patterns among an electronic community of prospective elementary teachers that participated in the pre-student teaching field experience during spring 2000. During the field experience the prospective elementary teachers had to go to schools twice a week to observe and teach a number of lessons.

Literature Review

Various studies have demonstrated that collaborative learning on the Internet can be beneficial (Bonk, Malikowski, Angeli, & East, 1998; Hmelo & Guzdial, 1997; Lee & Songer, 1998; Suthers, Toth & Weiner, 1997).

Lee and Songer (1998) examined the discourse patterns among the electronic community of learners who participated in the collaborative Internet-enhanced learning project, called Kids as Global Scientists (KGS). This project can be described as an electronic community of children whose goal is to understand natural weather phenomena by collecting and exchanging their observations and ideas with other participants from five continents. A feature of this project was the web-based message board, which allowed users to post, read and respond to other messages. The messages posted on the board were analyzed in order to study how participants were able to build a socially constructed knowledge community through electronic discourse (Lee & Songer, 1998, p. 169). The analysis of the electronic discourse revealed that participants practiced scientific inquiry and that they developed a 'social glue' that encouraged them to work together and share each other's experiences.

Audet, Hickman, and Dobrynina (1996) used the computerized journaling in an advanced physics class, in order to investigate the implications of a practice that creates opportunities for groups of science students to share thoughts and observations, defend viewpoints, and negotiate consensus about their thinking. They stated that writing in learning logs provided a vehicle for students and teachers to make their knowledge public, and build an atmosphere for valuing conceptual understanding for others.

Research by Bonk, Malikowski, Angeli, and East (1998) was designed to foster prospective teacher learning of educational psychology by creating a Web-based learning community using actual case situations these future teachers had experience during their field observations. The findings of this study suggested that the prospective teachers were heavily involved in electronic writing; they were sharing problems and events, asking for help and offering advice. Another interesting finding was that few prospective teachers' electronic postings were grounded or justified in course material. As other researchers discovered (Merseth, 1991), when prospective teachers converse electronically with their peers about their field experiences, they post too many surface level ideas and pithy remarks such as the simplistic "I agree" or "That's what I think too".

As disclosed in similar research by McIntyre, Byrd, and Foxx (1996) the analysis of e-mail dialogue for message themes, pre and post surveys, and student teacher and supervisor interviews found that the students in these conferences were mainly focused on emotional support and describing similar teaching experiences they observed rather than on links to their pedagogical content knowledge or personal reflection on one's teaching experiences (Bonk, Malikowski, Angeli, & East, 1998, p. 273).

Research background and methods

The prospective elementary teachers were communicating for one semester with their instructor and peers using Course Info, developed by Blackboard.com®: a web-based (http://www.blackboard.com/courses/495B), course management environment that integrates synchronous and asynchronous collaboration. Prospective elementary teachers were asked to submit an electronic reflective journal entry each week and to give feedback to at least one of theirs peers. These journal entries provided them the

opportunity to reflect on and integrate observations and incidents from the field experience with concepts, principles, models and theories studied in methods courses. While writing the journals, prospective elementary teachers were expected to apply what they have learned in method courses. They were asked to include: an explanation for why events unfolded as they did, an analysis of why a certain individual behaved in a particular way, a description of how some educational concept, theory, or model was or might have been applied to this situation. All discussions were saved and archived for in-depth content analysis. The first author served as both instructor and primary researcher while guiding prospective elementary teachers' reflection on their teaching and learning experiences. The second author served as a consultant of the data analysis.

Research questions

At the most general level this research aimed to answer the question: What kinds of patterns characterize this kind of electronic discourse? More specifically this research addressed the following questions:

- What topics tend to spur the discussion and interactivity?
- What are the prospective elementary teachers' experiences with the use of technology in their science lessons?
- To what extent do prospective elementary teachers connect their field experiences with their method courses?
- To what extent are prospective elementary teachers' conversations focused on links to pedagogical content knowledge and personal reflection?

Participants

The participants of this study consisted of ten prospective elementary teachers enrolled in a section of CI495B, the pre-student teaching field experience. Field experience focuses on lesson design, teaching, and classroom management as preparation for student teaching, as well as investigation into issues associated with educating diverse learners. During this experience, prospective elementary teachers were at the schools two full days a week for ten weeks and for one full week towards the end of the semester. They specifically had to design and teach science lessons using basic presentation and communication technologies. Twelve prospective elementary teachers were registered for the specific section of CI495B but only ten of them volunteered to participate in this study and their names were not revealed until the grades were submitted.

Qualitative Analysis

The journals of the participants were copied into a word-processing file and several features of the texts were determined, including number of words in the entire journal and the number and the percent of words for every category. The first analysis of the journals was undertaken to determine what types of information the prospective elementary teachers chose to include in their journals. The second analysis was based on Bonk, Malikowski, Angeli, and East (1998) work regarding a web-based case conferencing for prospective teacher education. Electronic transcript conversations were coded for discourse type and degree of justification and reflection.

The content analysis scheme included the following forms of electronic discourse: content of the messages, social acknowledgments, descriptions of incidents, interpretation

and reflection, unsupported opinions and statements, justified opinions and links to method courses.

At the end of the semester 70 journals were chosen for content analysis that represents all of the prospective elementary teachers' postings. Furthermore, only 41 replies were chosen to be analyzed because the rest of them were considered to be irrelevant to the field experience or found to be repetitions of others.

A reliability check was conducted in order to determine whether the coding scheme was appropriate and could be reproduced by other researchers. Three doctoral students and a professor from the science education field analyzed three journals together and they came to agreement about the coding scheme. The reliability check resulted in an agreement of 85%.

Results and Discussion

The intensive analysis of prospective elementary teachers' conversations yielded many significant insights into the nature of their beliefs, philosophies, struggles and concerns. Course Info provided prospective elementary teachers the opportunity to share their thoughts and observations while engaging in discussions with their peers. The prospective elementary teachers used Course Info to share their personal struggles regarding teaching, to report interesting stories and incidents that they had observed in the field, to criticize 'old-fashioned' teaching methods, to communicate their concerns, to make explicit their fears and insecurities, to offer advice and support to their peers and to ask for a lending hand. The issues that most of the participants talked about are presented in Table 1.Five issues were mainly discussed by the participants: classroom management

issues, the use of technology in science teaching, curriculum issues, multiculturism issues, and feelings of confidence as teachers.

Table 1

Issues discussed in the electronic conversations

Issues	Percentage
Classroom management	45
Use of technology in science	17
Critique of the curriculum	16
Multiculturism	9
Feelings of confidence	13

These five topics seemed to gain ground over others. The issue that most of the prospective elementary teachers referred to was that of classroom management and having to deal with discipline problems. Forty five percent of the journals described situations about misbehavior problems and classroom management. Moreover, seventeen percent of the discussion was devoted to the use of technology, and sharing experiences with the use of probeware in science lessons and critique for their mentor teachers for not making use of the available technology. Furthermore, sixteen percent of the discussion was related to critique about the curriculum, the use of the textbooks, teacher-centered methods, the use of drill exercises and non- inquiry questions. A small percentage (nice percent) was dedicated to issues of multiculturism and black history and lastly thirteen

percent of prospective elementary teachers' discussion was rotated around their feelings of confidence as teacher.

For each category of the content analysis scheme the percentages were as follows as the average for journals content:

Table 2

Schemes developed among the journals

Scheme	Percentage
Social acknowledgment	28
Descriptions	37
Reflections	34
Unsupported statements	<1
Justified opinions	<1
Links to method courses	<1

Less surprising findings in similar research given by Merseth (1991) showed that not only were direct links to text and class resources extremely limited, few students responses were controversial in nature. As other researchers have discovered, when prospective teachers electronically converse with their peers about field experiences, they post too many surface level ideas and pithy remarks. As disclosed in Merseth's research, students in these conferences were mainly focused on emotional support and describing similar teaching experiences than on links to their pedagogical content knowledge or personal reflection to one's teaching practices.

Furthermore, participants' feedback was consistent to the most part by different kinds of social acknowledgements, unjustified opinions and emotional support. As it is indicated in similar study by Bonk, Malikowski, Angeli, and East (1998) more than a third of the coded responses of the prospective teachers contained some form of social acknowledgment and general feedback.

The prospective elementary teachers reported their disappointment about the lack of computers in their schools and they also commented on their mentor teachers' techno phobia. In addition, all the participants referred to the fact that their students showed increasing interest in using technology in science lessons. Nine out of the ten prospective elementary teachers stated that they felt comfortable and confident with their knowledge to use certain technology tools in science teaching. However, they reported that they did not enjoy the technology lessons they taught very much because they faced many discipline problems due to the small number of computers available in the class.

Further Research

This analysis of discourse revealed the issues with which prospective elementary teachers were concerned and illuminated their insights and beliefs about teaching. In addition, the research generated many questions about how prospective elementary teachers make use of technology in science teaching and how they transform theory into practice with the tools that are available at the schools. Further efforts are necessary to investigate ways to integrate the topics that prospective elementary teachers are more concerned about into method courses along with ways to engage them in meaningful reflection.

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INQUIRY-BASED RESEARCH PUBLISHED IN *I WONDER: THE JOURNAL FOR ELEMENTARY SCHOOL SCIENTISTS* (1992-2000)

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Science education reform efforts in the USA stress the need for students at all levels to conduct and report scientific inquiry (AAAS, 1993; National Research Council, 1996). Typically, this reporting takes the form of a student or small group of students explaining their inquiry project in front of their classmates or writing a lab report for their teachers. There are few mechanisms for students to communicate their investigations of science beyond the walls of their classrooms. *I Wonder: The Journal for Elementary School Scientists* is unique in that it provides a mechanism for disseminating elementary students' investigations of science in a form that is analogous to printed journals within the scientific community *(Note: I Wonder* was published from 1992 until 1995. From 1996 to the present, *I Wonder* appears as one section in *Great Blue: A journal of student inquiry*, see Beeth & Wagler, 1997).. Our analysis of the 617 student inquiry articles published in *I Wonder* from1992-2000 offers (a) an overview of *I Wonder* as a tool to promote authentic student inquiry (Andersen, in review) and (b) an examination of the research questions and investigative procedures used by these students. We are particularly interested to know if the type of student generated inquiry represented in *I Wonder* articles is "scientific" or "engineering." Analysis of the articles published in *I Wonder* provides an excellent opportunity to see how these elementary students are responding to instruction presented as inquiry.

The Heron Network (a group of elementary school teachers and students in the Madison [WI] Metropolitan School District and surrounding area) has published *I Wonder* annually since 1992 (Beeth & Wagler, 1997). The purpose of *I Wonder* is to promote scientific discourse

among elementary students through the publication of their research in a journal, similar in some ways to the scientific discourse within a community of scientists. Articles published in *I Wonder* facilitate scientific discourse for the students and teachers involved in the Heron Network in two ways. First, *I Wonder* serves as an outlet for students to communicate their science inquiry projects to others. The journal is distributed annually in paper form to students within the Network as well as via the Internet (http://danenet.wicip.org/heron/Description.html). Teachers in the Heron Network help students write articles for dissemination–an uncommon genre of writing in most elementary schools. Preparing articles for publication in *I Wonder* helps these students understand the essential role that communicating one's research to others plays in professional scientific communities. Second, past issues of *I Wonder* serve as a repository for topics that students in the classrooms of Heron Network teachers have investigated. In a sense, past issues represent what students collectively learned and how they conducted their scientific investigations. Each Heron Network teacher requires his or her students to read past issues of *I Wonder* before proposing a new investigation. In this way, students emulate the activities of professional scientific communities by determining what is already know about a topic before they begin an inquiry project. In this paper, we analyze articles published in *I Wonder* from 1992-2000 to determine which science topics are selected for investigation and, more importantly, the methods students used when conducting and reporting an investigation. We were interested to know if the inquiry reported in *I Wonder* more closely represented "scientific" thinking or "engineering" thinking.

Theoretical background

The research literature in children's scientific thinking suggests several routes of analysis for the student inquiry articles published in *I Wonder*. Bybee's (2000) interpretation of Joseph

Schwab states that there are three main sources for children's questions: first hand manipulation of physical materials; printed resources such as textbooks or earlier editions of *I Wonder* journals; and students' life experiences. In the first of these, children use or manipulate physical materials in ways that allow them to answer questions about the materials themselves. Second, print resources frequently suggest questions for students to study in a "cookbook" type manner where the answer is usually assumed to be predetermined. Last, children are naturally curious about how things work. When children are allowed to investigate their own questions they tend to use what they already know to stimulate additional thoughts and actions resulting in the generation of new knowledge (Chiappetta, 1997). As will be demonstrated in this paper, students draw upon their personal experience for inquiry projects more frequently than any other category. (see Table 2).

A second route of analysis differentiates "scientific" thinking versus "engineering" thinking. When investigating causal systems, children tend to focus initially on producing desirable outcomes (often by trial-and-error) instead of performing systematic explorations to understand the causal structure of the task (Schauble, Klopfer, & Raghavan, 1991). Our initial analysis of the articles in *I Wonder* from 1992-2000 identified those articles that claimed to use procedures associated with experimental design or engineering approaches. Articles identified as "scientific" and "engineering" were further examined to determine whether these investigations produced only the desired outcome or whether they also generated new scientific knowledge for the author(s). Our analysis couples this information with the source of students' questions to support conclusions regarding overall change in the nature of science learning represented in *I Wonder* from 1992-2000.

Methodology

All articles published in *I Wonder* between 1992 and 2000 (N=617; see Table 1) were read by both authors of this paper. Information in the text of each article was coded for the source of the student(s) question, topic investigated and method(s) of gathering data (see Tables 2, 3 and 4 respectively). Definitions for all codes are presented in Appendix A and examples of selected titles placed in some topic categories are found in Appendix B. The entire list of codes represents, for us, lines of inquiry that make sense to the students and their teachers, although they may not exactly represent scientific notions. For example, the codes "animal-pet" and "animal-behavior " are not mutually exclusive. However, the distinction we made with respect to these topics indicated whether an animal was being trained to perform a predetermined task -- "What tricks can cat's do best?" (Turnbull, 1999) or "The effects of exercise on how fast mice can get through a maze" (Benish, Fleming, & Whitaker, 1996); or observed in a natural setting -- "Observing squirrels" (Wichert & Casale, 1995). This degree of flexibility in our coding system was also necessary as teachers in the Heron Network occasionally directed students to specific topics if they failed to come up with one of their own (i.e., observational studies of their backyards in 1996 and 1997).

Descriptive statistics for the complete data set are presented in Tables 2, 3 and 4 below. Each cell in these tables contain two numbers – the number of articles placed in a category followed by the proportion (in parentheses) of all articles that category represents for that a given year. This is followed by descriptions of articles that illustrate "scientific" thinking versus "engineering" thinking. In addition, several of the examples clearly show the importance of discourse between students and their completion of the project. A series of articles on the "Pulley Project" is then presented that illustrate change in the sophistication with which several groups of

students investigated this topic over a number of years. Our analysis illustrates the extent to which articles published in *I Wonder* represent inquiry-based investigations that are scientific versus investigations that employ engineering approaches. There are no obvious trends in the data for source of student question(s). However, it should be noted that students who published in *I Wonder* were not relying on one source to the exclusion of all others.

Table 1

Articles Published in *I Wonder* (1992-2000)

Year	# Articles
1992	16
1993	63
1994	93
1995	93
1996	70
1997	56
1998	85
1999	87
2000	54

Table 2

Source of Student Question(s) (1992-2000)

	Year								
Source	92	93	94	95	96	97	98	99	00
I Wonder Journal		7 (.10)	7 (.08)	9 (.10)	6 (.08)	3 (.05)	7 (.09)	2 (.02)	5 (.09)
Teacher	7 (.40)	9 (.11)	4 (.04)	20 (.22)	20 (.30)	19 (.34)	13 (.16)	2 (.02)	7 (.13)
Peer		4 (.06)	7 (.08)	14 (.15)	10 (.14)	8 (.14)	10 (.12)	3 (.03)	4 (.07)
Parent/other adult	1 (.10)	2 (.03)	2 (.02)	3 (.03)	3 (.04)	3 (.05)	1 (.01)	2 (.02)	2 (.04)
Experience	3 (.20)	30 (.50)	30 (.33)	32 (.34)	14 (.20)	17 (.31)	30 (.36)	9 (.10)	19 (.35)
Pop culture			5 (.05)	4 (.04)	3 (.04)	3 (.05)	6 (.08)	1 (.01)	0
Unknown source	5 (.30)	11 (.20)	38 (.40)	11 (.12)	14 (.20)	3 (.05)	12 (.15)	68 (.79)	17 (.32)
Total	16	63	93	93	70	56	85	87	54

Table 3

<u>Topic investigated (1992-2000)</u>

Topic	Year								
	92	93	94	95	96	97	98	99	00
Animal (behavior)	1 (.06)	1 (.02)	8 (.09)	4 (.04)	6 (.09)	2 (.04)	2 (.02)	4 (.05)	7 (.13)
Animal (insects)		3 (.05)	1 (.01)		1 (.01)	2 (.07)	4 (.05)	1 (.01)	
Animal (invertebrate)			2 (.02)	1 (.01)		1 (.02)	1 (.01)	5 (.06)	
Animal (macro)	2 (.13)		5 (.05)	7 (.15)	2 (.02)	4 (.07)	2 (.02)	1 (.01)	
Animal (micro)			2 (.02)	1 (.01)		1 (.02)		1 (.01)	1 (.02)
Animal (pet)			3 (.03)	4 (.04)		1 (.02)		5 (.06)	6 (.11)
Animal (vertebrate)		7 (.11)	12 (.13)	14 (.15)	11 (.16)	5 (.09)	12 (.14)	10 (.12)	
Chemistry	1 (.06)	8 (.13)	6 (.07)	8 (.09)	3 (.03)	5 (.09)	8 (.09)	17 (.20)	6 (.11)
Earth Science		3 (.05)	4 (.04)	9 (.10)	4 (.05)	4 (.07)	6 (.07)	16 (.18)	3 (.06)
Engineering	1 (.06)	2 (.03)		5 (.05)	5 (.07)	1 (.02)	3 (.04)	4 (.05)	3 (.06)
Environment	4 (.25)	4 (.07)	5 (.05)	2 (.02)	10 (.14)	4 (.07)	11 (.12)	7 (.08)	9 (.12)
ESP	1 (.06)		1 (.01)	1 (.01)		1 (.02)			
Human Physiology		1 (.02)	2 (.02)	3 (.03)	2 (.02)	1 (.02)	4 (.05)	3 (.03)	3 (.06)
Learning	1 (.06)	2 (.03)	3 (.03)	1 (.01)				1 (.01)	

(Table 3 continues)

(Table 3 continued)

Memory		1 (.02)	1 (.01)	1 (.01)	1 (.01)	2 (.02)	5 (.06)		
Mold		1 (.02)	2 (.02)		1 (.01)	2 (.02)	3 (.04)		2 (.03)
Personal Preference	1 (.06)	5 (.08)		5 (.05)	2 (.02)		1 (.01)	3 (.03)	1 (.02)
Physics		6 (.10)	13 (.14)	9 (.10)	11 (.16)	8 (.14)	7 (.08)	1 (.01)	9 (.12)
Plants	4 (.25)	19 (.30)	18 (.20)	14 (.15)	9 (.13)	9 (.16)	11 (.12)	7 (.08)	4 (.07)
Psychology			5 (.05)	1 (.01)	2 (.02)	2 (.04)	5 (.06)		
Other				3 (.03)		1 (.02)		1 (.01)	
Total	16	63	93	93	70	56	85	87	54

Table 4

Method(s) of investigation (1992-2000)

	Year								
Method	92	93	94	95	96	97	98	99	00
Experimental	12 (.75)	38 (.60)	16 (.17)	23 (.25)	19 (.30)	20 (.36)	21 (.25)	22 (.25)	10 (.30)
Invention			6 (.07)	7 (.07)	7 (.01)	6 (.10)	9 (.10)	3 (.03)	5 (.09)
Literature search	1 (.06)	1 (.02)	8 (.09)	7 (.07)	3 (.04)	2 (.04)	12 (.14)	25 (.29)	2 (.03)
Observation	2 (.13)	11 (.17)	34 (.40)	30 (.32)	30 (.43)	22 (.40)	22 (.40)	21 (.24)	21 (.40)
Survey		4 (.07)	15 (.16)	2 (.02)	3 (.04)	2 (.04)	10 (.12)	7 (.08)	3 (.06)
Trial and error	1 (.06)	9 (.14)	4 (.04)	20 (.21)	4 (.05)	4 (.07)	6 (.07)	9 (.10)	11 (.20)
Total	16	63	93	93	70	56	85	87	54

Scientific versus engineering thinking

Data in Tables 2, 3 and 4 above characterize the 617 articles published in *I Wonder* at a nominal level. Articles we selected to illustrate "scientific" thinking versus "engineering" thinking are presented below. These articles represent either (a) a single article that contains elements of scientific or engineering thinking or (b) a series of articles that build on one another as they investigate a topic. In the later case are multiple articles across several issues of *I Wonder* on topics such as batteries, acids and bases, observation of natural phenomena in students' backyards, the growth of crystals, or building some object for a specific task. On the other hand, individual articles that contained elements of scientific or engineering thinking were ubiquitous.

Our purpose here is to present only select samples of the articles that we believe represent these two categories.

What makes people sneeze?

Limaye's (1995) question ("What makes people sneeze?") came from watching a presentation by high school biology students in his district. Watching this presentation made him curious to investigate this topic and he began by first asking the biology teacher for help with his inquiry project. The high school biology teacher provided Limaye with a box of materials he would need to set up his experiment. He designed an experiment to test the reactions of his classmates to pepper, dog hair, chalk dust, and household dust. Each test item was presented to 26 subjects. Subjects rated their reactions to each item as sneezed, tickled, hurt, burned, nothing or other. Data were summarized across all 26 cases and displayed in a bar graph of reactions to each substance versus number of reactors. What is particularly interesting is that Limaye's analysis of his data led him to reject his original hypothesis as incorrect. Limaye stated, "I learned that pepper doesn't always cause a reaction, let alone a sneeze. I believe that a lot of sneezing happened due to an allergic reaction." In effect, Limaye demonstrated ability to reason from data to conclusions – in this case, rejecting his initial hypothesis that pepper causes sneezing.

Taste Buds

Barber (1996) published an article that addressed the question, "Where are taste buds strongest?" This question was posed after reading Gould-Werth's (1995) inquiry article. Barber tested three different liquids: saltwater, sugar water, and lemon juice. Her procedure clearly tested one liquid and one student at a time. Barber asked subjects to report where on their tongues the taste was strongest. Data were discussed anecdotally in the text of the article but and

not displayed in tabular form. What was particularly interesting in this case is that Barber actually talked with Alix Gould-Werth about revising the study she published in 1995. Barber reported, "I think I improved it a little, she [Gould-Werth] thinks I improved it a lot". The opportunity for Barber to speak with Gould-Werth before revising her work is a fundamental activity in science, one that was captured by these two authors as the these two *I Wonder* articles as well as many others.

Rolling Balls

West and Kress (1996) cited a prior *I Wonder* article ("Ramps and Racing" by Cotton & Osuocha, 1995), in their article on "Rolling balls." In addition to adding on to the information gathered in *I Wonder*, Kress had also done projects on momentum. With both of these experiences the students were able to plan their experiment. The students hypothesized " the higher the ramp got, the farther the ball would go." They measured the height and angle of the ramps as well as the distance a ball traveled down each ramp 100 times. West and Kress stated, "We had 'sets' and 'trials'. There were 10 trials in a set. There were 10 sets all together or 100 trials." These students showed their understanding of controlling a limited number of variables, and they collected a large data set from which to draw conclusions. In the end, they gave several suggestions of additional variables that might be interesting to study in the future, like the texture of the ball. West and Kress demonstrated understanding of scientific procedures and conclusions based on their study.

Crystals

The formation and observation of different types of crystals is an inquiry repeated several times in *I Wonder* journals. The original publication of research about crystals began with two different studies in 1993. First, Lee and Moffett (1993) began their research about how to make

crystals. Soon they learned that Moore (1993), a student in another classroom was also interested in the same topic. The two groups of students were able to share their research notes and work together on two different studies of crystals. The use of discourse between students working on similar projects added to the general knowledge base of both groups. Moore states "I got a lot of information from them. The information I got from them showed the different kinds of crystals you could make." She also went on to discuss additional resources like a university professor who helped the students gather the materials needed to complete their research. The result was two similar but different projects with Lee and Moffett (1993) implementing a charcoal garden and Moore (1993) the more traditional string and sugar method.

Crystal research did not end in 1993. Several students have continued to study the formation of crystals with different materials. For example, Powell (1995) published results from the use of different spices, such as sugar, salt, and pepper. Powell set up several different trials and compared the results. Wroblewski (2000) made additional changes by altering the number of food coloring drops added to give the crystals color. She hypothesized that "the more food coloring I added, the smaller the crystals would be." She went on to discover the amount of food coloring did not have an effect on the size of the crystals that were grown.

Examples of Engineering Articles

Combustion Engines

Payne (1999, p. 94) published an article that asked: "How does gas make an engine work?" This question is similar to other engineering type projects that ask questions about material objects. To answer this question Payne examined resources in the library and on the Internet. Ultimately he obtained the information he desired from an encyclopedia, information

that was then confirmed by a knowledgeable parent. In a section of his article titled "Problems and New Directions" Payne stated, "My problem was no book except the encyclopedia had any information..." Payne's *I Wonder* article represents, for us, an approach to inquiry that relied on analyzing (reading?) known information without engaging him in doing hands-on inquiry related to this topic. However, searching existing literatures is an essential first step in science inquiry.

Making a Cat Food Machine

Frankowski and Yang's (1995) project, "Making a cat food machine", started with the question: "Can we make some sort of machine that lets a cat feed itself?" The final product in this case is a device that, if perfected, would solve a problem for these students. The idea for this project resulted from a conference with their teacher after their initial idea ("...about how cats and fish hear") was determined to be too difficult to study. These students built, tested, and re-tested their cat food machine on actual cats and themselves (because the cats failed to cooperate in the testing of the machine). Their prototype cat food machine included a cardboard box, popsicle sticks, and a cat toy that delivered cat food to a food bowl. In the end, they suggested changes to the cat food machine to get it to drop food more accurately into the bowl ("The cat food machine kind of worked but after the experiment there was cat food all over the kitchen floor"), and to their choice of materials ("If we had to do the whole experiment over again, we would make the cat food machine a little stronger and the box a little more tilted..."). The project these students completed represents several aspects of engineering in that they knew what they wanted to produce, they built, revised and tested a working model, and they made suggesting for improving their final product. Engineering projects similar to the one described here were also authored by Lawrence and Yang (1995, "Making a light bulb"), Evans (1995,

"Can fish go through a maze?") and Kress and Luck (1998, "Making and destroying balsa wood bridges").

Making a Pulley System Down to the Office

The Pulley Project, as it came to be known by teachers in the Heron Network, represents several significant points about engineering projects publishing in *I Wonder*. First, Heikkinen and Hunter approached the building of a pulley system to the office as an engineering task in 1992. These students spent considerable time determining how much string would be needed and gathering different kinds of pulleys to build a prototype that was functional. In subsequent years, after reading articles published by previous students, the questions posed were much more sophisticated in that they began to ask fundamental questions about the physics underlying the construction of the pulley system. After reading the article by Heikkinen and Hunter (1992), Klein, Jeanne and Smalls (1993) decided to measure the force required for lifting an object with one, two and no pulleys as a prelude to designing their final system. Their question moved the pulley project away from an engineering task and toward a more scientific investigation of the mechanical advantages of pulleys. Cole (1998) and Medina and Sinderbrand (1996) continued this work on the pulley project by investigating different configurations of pulleys – fixed, movable, and block and tackle.

The pulley project held the interests of a considerable number of students from 1992 through 1998. Undoubtedly, this project challenged students to solve a practical problem for them – conveying the attendance card to the office and back, thus saving time and effort. The first group of students approached the Pulley Project as an engineering task – investigating the physical capabilities of string and pulleys, measuring the distance to the office, assembling all the necessary materials, and then building a prototype that was functional. Later groups of

students investigated this problem in ways that are similar to those within the scientific community, namely by reading previous research and modifying the question, their methods of investigation or both to enhance fundamental knowledge about the system of interest. In this way, students' use of *I Wonder* paralleled the use of published scientific literature by those in a scientific community.

Implications for Future Research

The publication of articles in *I Wonder* allowed these elementary school students to participate in scientific discourse within a community of scientists. In particular, it allowed these students to read and modify the previous work of their peers over the years 1992-2000, most notably in the Pulley Project. In one sense, *I Wonder* functions not just as a record of student inquiry but as a stimulus for inquiry investigations that result in the production of new knowledge – at least new to these students. This has allowed these students to build a community in which they and their peers determine what to study and how. It also results in the investigation of topics in a depth not common to the science teaching with which we are familiar.

The analysis of *I Wonder* articles as "scientific" or "engineering" in this article can easily be extended to address other questions in the future. For example, many articles in *I Wonder* contain significant questions of a personal nature (e.g., "How many times are African-American's cited in science books?", Mogaka, 1995), one is written in Spanish (i.e., "Agua sal, agua acida pura agua y plantas," Cautopozota, 1994), many contain sophisticated data presentations (see graphs of housing supply and demand before and after the 1906 San Francisco earthquake by Manuelli, 1996), and others resulted after presentation of a topic by an expert (i.e., Testing memories, Garcia, 1998). Certainly the impacts these had on students' inquiry projects should be

investigated. In addition, analysis of an individual student's ability to present their scientific or engineering projects when they published more than one *I Wonder* article (168 people published more than one article) would be worthy of further investigation. When analyzing *I Wonder* as we did, we also noted that some authors used assistance from a parent or other adult. Following-up with these authors to determine the relative contributions of one or the other could also be informative. It was our intent in this article, however, to characterize all articles published in *I Wonder* from 1992-2000 as a starting point for further investigations of these inquiry projects.

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Appendix A

Definitions for data codes

Source of question

I Wonder Journal - mentioned an article in a previous issue of *I Wonder*
Teacher - article mentioned teacher as source of idea
Peer - article mentioned a peer as source of idea
Parent or other adult- article mentioned an adult not connected with teaching as source of idea
Experience - article mentioned some previous experience as source of idea
Pop culture - article mentioned television or other media as source of idea

Topic investigated

Animal-behavior - attempts to train or naturalistic observations of an animal
Animal-insect - studies of insect life cycles
Animal-invertebrate - studies of marcoinvertebrates in classroom or natural settings
Animal-macro - studies of Daphnia (maintained by several teachers)
Animal-micro - studies of protozoa
Animal-pet - studies of a domestic animal in a controlled environment
Animal-vertebrate - studies of large animals in their natural environments
Chemistry - studies exploring the properties of chemicals, or heat
Earth science - studies of earth materials or geologic events
Engineering - attempts to make something of practical use
Environment - studies of interactions of biotic and abiotic factors in natural settings
ESP - studies of paranormal phenomena
Human physiology - studies of physiological response to a stimulus
Learning - studies of cognition
Memory - studies of recall
Mold - studies of non-vascular plants
Personal preference - studies of personal preferences
Physics - studies of motion, light, electricity, etc.
Plant - studies of any vascular plant
Psychology - studies of human perception, mood, etc.

Method of the investigation

Experimental - controlled one or more variables
Invention - intent was to make a know device better or more efficient
Literature search - summarized information in print or electronic resources
Observation - observed some event but did not try to duplicate it
Survey - collected information form others through questioning
Trial and error - repeated attempts to cause something to happen

Appendix B

Article titles categorized by topic

Chemistry - " Creating Hydrogen gas", " How to make a battery"
ESP - "ESP", " ESP concentration"
Human physiology - " Heart rates in boys and girls", " Do funny movies affect pulse and body temperature?"
Learning - "Attention in third and fifth graders", " What is ADD?"
Personal preference - " Testing sugarless bubble gum", " What are you thirsty for?"
Plant - " Cross pollinating Arabidopsis plants", " Plants in different light"
Psychology - " Food and dreams", " Before and after recess behavior

PRE-SERVICE SCIENCE AND MATHEMATICS TEACHERS AS CULTURAL AGENTS: A TRANSFORMATIVE STUDY

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Pre-service Science and Mathematics Teachers as Cultural Agents

"Teaching," as Stigler and Heibert (1998) remind us, " is a cultural activity" (p. 4). The cultural dimensions of teaching engage both student and teacher in a diverse, multilevel process that both creates and supports cultural scripts about how one lives in the world. What this research endeavored to accomplish was a more systematic understanding of how a teacher can transform culture in an effort to create a more democratic education.

At a deeper level, the manner in which teaching reflects and supports culture depends upon whether a teacher believes that students are passive receivers of knowledge or active creators of knowledge. Paulo Friere (1993), the Brazilian educational philosopher, has written extensively about the manner in which conservative educational institutions seek "..to domesticate students" (p. 53). According to Friere, teachers often employ a "banking" method of teaching, which assumes that students are empty vessels that need to be filled. In this case, the teacher is seen as the primary disseminator of knowledge and is the focal point of educational discourse.

For the purposes of this research, we endeavor to instill in our preservice students a transformative model of teaching. It is our belief that students and teachers should engage in mutual construction of knowledge. In this case, the teacher and student share in the development of knowledge and are, in fact, equal partners in education discourse.

Since teaching is a cultural activity, it is paramount that teacher and students engage in discourse as to the manner in which curriculum can be transformed so that all interested

parties can participate. The focus of this research is on science and math education and cultural agency. As we see it, science and mathematics education in America tends to perpetuate the banking method of teaching. Genarelly, students are given information in lecture formats, tested with very rigid and formal instruments, subjected to monotonous drill and review activities, and are generally not encourage to pursue inquiries that are of interest to themselves.

At the same time, current practices in science education are excluding women and ethnic minorities from full participation in science and math. This has created an elite, exclusive pool of scientists. Effective cultural agents in science and mathematics education possess the ability to teach in a way that is inclusive of a variety of ethnic and cultural perspectives as well as gender.

Given the current climate in American science and math education, it is critical that institutions that train teachers develop in their clientele the attitude that are teachers are cultural agents. By this we mean to say, that cultural agency strives to transform culture to improve both teaching methodology and to destroy the barriers that are keeping so many talent women and minorities out of technical and scientific fields of study.

This study endeavored to focus on the relationship between content instruction and social activism. It is our belief that current science and mathematics teaching methodologies are based upon certain cultural precepts that are ineffective. Stigler & Hiebert (1998) state that it is not possible to improve teaching by improving/changing elements. When individual components are changed, the system views these changes as damage andendeavors to repair them. They further assert that meaningful curricular changes can only occur when cultural scripts about teaching are transformed. This transformation is a cultural activity therefore requiring cultural agency.

Cultural Agency

As was noted earlier, it is our belief that teachers are cultural agents. Furthermore, science and mathematics teachers should be regarded, as Freire noted (1990), as active subjects in the creation of culture not passive objects. This requires that the educator develops a critical consciousness as to the manner in which science and mathematics is taught. This allows the teacher to comprehend the inaccuracy of stereotypes and engage their students in reformulating their conceptions of who can participate in the creation of scientific knowledge. All students can and should participate in scientific endeavors (National Research Council, 1996; Rutherford & Ahlgren, 1989). Current practice in science and mathematics education excludes many individuals on criteria that are separate from intellectual ability. The exclusion from science and mathematics is based upon arbitrary lines drawn along ethnic and gender identities.

As cultural agents, science and mathematics educators have the charge of transforming not only teaching methodology but cultural patterns as well (Stigler and Hierbert, 1998). Cultural agency, therefore, requires that educators broaden their understanding of teaching science and mathematics to transform the methods of science and mathematics education and the broader issues of studying cultures, including self, to embrace more inclusive and progressive teaching methodologies.

The manner in which one achieves cultural agency is multifaceted. However, a crucial component of cultural agency is that of reflection upon one's role within a cultural context. Equally critical is how self-identity influences action within a culture. For example, girls oftentimes self exclude themselves from participation in science and mathematics because of imposed gender roles (Sadker & Sadker, 1994). An effective science and mathematics

educator should include the deconstruction of gender and ethnic stereotypes in their science and mathematics curriculum overall.

A teacher who is also an effective cultural agent is conscious of theprevailing discrimination in science and mathematics education. This educator is able to name the issues and determine effective interventions in dismantling stereotypes. Some of these interventions would include identity clarification and transformation (Brickhouse, Lowery, & Schultz, 2000), dialogue and social action (Freire, 1970 & 1993), and the critical appraisal and reworking of current images of scientists. In this manner, the science and mathematics teacher plays a considerable role in increasing the number and diversity of participants in science and mathematics.

Context of the Study, Research Focus, Data Collection and Analysis

Context

Radford University, where this data was collected, is a comprehensive university of 9,000 students in Southwestern Virginia. This region is 96°s Caucasian and 4% African-American. The university is 86% Caucasian, 100 African-American and 40 other. Many of Radford's students are first generation college graduates.

Radford's field placement schools are predominantly rural, poor and culturally Appalachian (e.g., on the first day of deer hunting season, the majority of high school males are absent from school). One exception to the above is a high school which services the state's largest university, Virginia Polytechnic Institute. This school services university employees' children and has a significantly higher SES than surrounding schools. Two other exceptions are the high schools in Roanoke City. Roanoke is city of 98,000 people, which is forty miles

from the university. Roanoke has two high schools that are predominately African-American (in excess of 500).

Research Focus

We sought to assist our students in an exploration through dialogue of the definition of cultural agency and the connections between cultural agency and teaching.

Researchers

The researchers, a Caucasian woman and a Hispanic man, sought to encourage the students to consider their personal teaching metaphors and how these metaphors and how these metaphors impacted their interactions with diverse students.

Subjects

This yearlong ethnographic study followed six pre-service science and mathematics and one mathematician from the fall of 1999 to the summer of 2000. During the fall, these students were blocked into courses in science and mathematics teaching methods, technology and special education. During this time, the students also spent a minimum of ten hours per week in a public school for their practicum experience. During the spring the students were enrolled for twelve hours in a student teaching, this included biweekly seminars. Of these six students, two were males, five were biologists, and one was an earth scientist. One student was an Asian American.

Data Collection

All student teachers were observed teaching in their assigned classrooms a minimum of 4 times during the semester. The observations were a minimum of 45 minutes, which included a pre and a post observational conference with the student teacher and the cooperating teacher.

The investigators took field notes during each observation. The student teacher and the cooperating teacher reviewed these notes. The field notes were checked for consistency with the State and National frameworks.

The students kept reflective journals for the entire school year. Students' reflected on their daily classroom experiences, their feelings about teaching in general, responses to classroom activities, readings, and special seminars on transformative education/cultural agency.

Written lesson plans were collected weekly for all classes during student teaching. These were read by the investigators and returned to the students with written comments.

Data Analysis

Data were analyzed recursively using the constant comparative method (Glaser & Strauss, 1967). Patterns were discerned and then compared between the triangulation points (Bogdan & Taylor, 1975; Bogdan. & Biklen, 1982) of journals, field notes which included interview notes, lesson plans and across the findings of the two researchers.

Comparison of data analyses from the researchers was used to identify areas of agreement and disagreement on interpretation(s) for this study (Cohen, 1981). Qualitatively the researchers independently reviewed the materials for patterns to identify and discover differences in presentation and the meaning that the similarities and differences represented.

The two researchers read each other's findings and sought agreement about the patterns discerned. The discussions in this text reflect only patterns of agreement.

The Results

All of the students were able to name problems and issues more concretely by the end of the year ("...High School is made up of both black and white students with many students from foreign background. I noticed that the higher level courses and in the "elite" programs

such as "Centers" and Governor's school, the students were mostly of the white background. My "academic" classes were composed mainly of students from black background and from the lower Social Economic Status. They say tracking does not occur, but it is very prevalent if you take a closer look at the make up of the different levels of academics. This sends a message to those students in the lower level classes. It is saying that very few of them are going on to college or that they are going to make anything out of themselves."). Some students were able to articulate more insightful understandings as how to choose science and mathematics teaching methodologies that did not exclude minorities and women. ("Some concepts were easier taught by hands on lessons while other concepts with direct teaching. This led toward my planning varied lesson plans so all student could learn."). Some of the students were able to perceive that exclusion is a cultural phenomena and not an individual one (e.g., tracking). One student, an Asian-American male, was able to articulate and implement strategies for creating an inclusive science and mathematics curriculum.

> Everyone can learn. It is my responsibility to teach students and to take part in their preparation for entering the civil society. School is not an island by itself, but is part of the learning process that includes the family, community and culture. I will use varied and multifaceted teaching methods. These methods will include hands on, visual, audio, written, electronic media, direct instruction, field experience (field trips, professionals, myself) and others. Since everyone is different, everyone does not learn by the same methods. By incorporating varied lesson plans, all students will be able to learn.

Two students developed lessons and/or unit plans that incorporated social consciousness in science and mathematics content. For example, one student teacher

developed a unit on water pollution which encouraged his students to consider how environmental issues effected their lives. As a result, of completing this unit the high school students also examined their social responsibilities in maintaining viable environment.

For the most part, however, the students were unable to utilize their understandings of the role of cultural agency in effective science and mathematics education.

Conclusion

This study shows that our interventions were unsuccessful in assisting our students to become cultural change agents. Also of the students were unable to apply their new knowledge of the problems and issues of cultural agency in meaningful ways. Most of them never developed the necessary interpersonal skills or ability to act which would have enabled them to work authentically with females and students of color.

All six students demonstrated significant improvement in their overall teaching competency. They were able to deliver content in a variety of ways but remained unable to enact cultural change. The exception to this finding was the male Asian-American student. This student was placed in a Roanoke City school. His classes were all "B" level which effectively meant the students were not college bound. Initially, this young man had difficulty relating to his predominately black students. He did not understand their language or culture. Because of his own experiences as a person of color he persisted and constantly reflected on how to relate to his students effectively. By the end of his student teaching experience, he had become both a social advocate and a teacher for all his students. When searching for a teaching position, he sought out a high school with a majority of students of color and accepted this position even though he had several offers from more affluent, predominately white schools. The other five students, however, focused their job hunting activities in school that mirrored their own backgrounds.

As mentioned, the other five students of this group were unable to promote and enact cultural agency over the year. These students experienced a number of stumbling blocks to their development as cultural agents. The first of these blocks was the immense amount of new information the students experienced. The great amount and intensity of information given the students at all levels prohibited deep reflection on the role of culture in learning. Secondly, these students had difficulty conceptualizing being an outsider within our mainstream culture. Being able to look beyond the box of one's cultural perspective was a challenge they could not meet within the context of student teaching. For these two reasons, the five students in this group experienced significant dissonance when working with students and, in particular students of color and females.

Discussion

This study demonstrates the necessity of on-going interaction with preservice teacher with respect to educating them as cultural agents who can enact cultural transformation. Also, this study demonstrates how field placements contribute to one's understanding about issue of educational equity for students of color and women in science and mathematics. The students who participated in this study also pointed out the need for continual reflections upon the dissonance one often experiences when one's cultural perceptions are challenged.

For these reasons, it is recommended that programs (1) expand the length of the interactions with pre-service teachers to a period of at least two years, (2) provide experiences for pre-service teachers in the field by placing them in schools that already have ethnic and gender diversity, and (3) develop and implement activities and dialogue sessions that deal with the dissonance stemming from interactions with diverse cultural groups.

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INCREASED SCIENCE ACHIEVEMENT FOR ADOLESCENT GIRLS

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Who says girls don't like science and math? The Sweetwater Union High School District has a successful program that motivates girls to not only enjoy science and math, but to excel in those areas. The Girl Power program is funded by the National Science Foundation. The components of the program are after school clubs, summer and intersession classes, parent involvement, counselor support and staff development. The middle school girls in our program report increased self-confidence in and enjoyment of, science and math. Pre and post testing indicates substantial academic improvement over the duration of the program.

One key aspect of the program's success is the active involvement of the local scientific community. Area scientists and engineers have volunteered to provide workshops for teachers, speak at career fairs, and act as mentors for the middle school girls. Successful women role models give the middle school girls a picture of the possibilities available to them in their future. The combination of mentoring and relevant hands-on activities in the classroom has led to a significant culture change among the young women in our program.

The after-school and intersession activities for middle school girls are organized around different themes. For example, the girls would learn about forensics, while doing simulated activities on blood typing, chromatography, etc. to enrich their understanding. Each unit also includes career and counseling activities. The units are designed to be fun and build the girls self-confidence in science, math and technology. Unit themes have included archeology, robotics, aerodynamics, engineering, and web design. The counseling component supports the

personal and social development of young women, enriching career exploration and academic achievement.

The Professional Development component trains teachers and counselors in strategies that enhance learning for girls. For teachers this would include methods for ensuring that all students are called on, and responded to, equally. We also show teachers how to use cooperative learning and rotate group roles to give all students equal experiences. Hands-on activities are strongly encouraged because research shows that these have a strong correlation with female success. Counseling training has focused on group counseling techniques and classroom activities. Topics include study skills, math anxiety reduction, and relationships. The ongoing collaboration between teachers and counselors provides a powerful environment for success.

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WHAT DO WE KNOW ABOUT STUDENTS' COGNITIVE CONFLICT IN SCIENCE CLASSROOM: A THEORETICAL MODEL OF COGNITIVE CONFLICT PROCESS

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Introduction

Cognitive conflicts have long been a part of psychological theories of cognitive change (Cantor, 1983). Despite many shifts of emphasis, the Piagetian account of development has always considered the concept of cognitive conflict, or the internal experience of opposing contractions, to be absolutely central in cognitive development. The concept figured in Piaget's earliest writings, and in Piaget (1985) it was developed into the equilibration model describing inner self-regulations (Roy & Howe, 1990).

Since 1980s, using cognitive conflict as teaching strategy has been very popular in science education research. A considerable number of researchers argued that cognitive conflict has an important/positive effect on conceptual change (Stavy & Berkovitz, 1980; Posner, Strike, Hewson, & Gertzog, 1982; Hewson & Hewson, 1984; Hashweh, 1986; Kwon, 1989, 1997; Thorley & Treagust, 1989; Niaz, 1995; Druyan, 1997; Lee, 1998).

However, there are still remained questions about the effect of cognitive conflict (Hewson, Beeth, & Thorley, 1998). Some researchers (Dreyfus, Jungwirth & Eliovitch, 1990; Elizabeth & Galloway, 1996; Dekkers & Thijs, 1998) argued that cognitive conflict strategies do not consistently lead to conceptual change. They said that even though students' ideas can be confronted with contradictory information through instruction, students frequently do not recognize conflict and sometimes the contradictory information can affect students negatively.

Vosniadou and Ioannides said that this dispute about the effect of cognitive conflict in learning science is not solved (1998, p.1214):

> "Is cognitive conflict a good strategy to produce conceptual change?" In order to answer these questions we need further research on the development of knowledge about the physical world and about the learning science.

So, as Johnson & Johnson (1979) mentioned in the statements at the beginning of this paper, we still have similar problems. At this point, we should think about basic questions. " What is the definition of cognitive conflict in learning?" More generally, "What is cognitive conflict that is aroused in our students?" And "how is it aroused?" There are very few researchers who tried to answer these questions.

We believe that to understand the real effect of cognitive conflict in learning science, at first we should answer the basic questions. In this study, we tried to answer these questions, and we discussed the implication of our study in education.

The Definition of Cognitive Conflict

Damon and Killen (1982) said, "Cognitive conflict has never been precisely defined." And up to now there is no literature that explains the definition of it in detail. It is difficult to find the definition of cognitive conflict in any dictionary, either. Even in the cognitive conflict chapter of a book that deals with only conflict, there is no definition. On the whole, researchers used many terms together with cognitive conflict to explain cognitive conflict situation. There are many terms that were used with similar meanings to cognitive conflict by each researcher:

> cognitive dissonance (Murray, Ames, & Botvin, 1977; Botvin & Murray, 1975), cognitive gap (Furth 1981), conceptual conflict (Johnson & Johnson, 1979), discrepancy (Siegel, 1979, Zimmerman & Blom, 1983), disequilibrum (Damon & Killen, 1982; Murray, 1983; Murray, Ames, & Botvin, 1977), internal conflict (Bodlakova, 1988), paradoxes (Movshovitz-Hadar and Hadass, 1990), psychic conflict (Cntor, 1983), socio-cognitive conflict (Bearison, Sol Magzamen, & Filardo, 1986)

Each researcher used one or two words according considering that there is similarity or little difference among the meanings of those words. For example, Smedslund (1961) used the word equilibration that was described by Piaget (1985). He suggested that equilibration may be similar to Festinger's cognitive dissonance or Heider's balance mechanisms.

Berlyne (1960) proposed the reason for using conceptual conflict instead of other words:

> Our own concern with conceptual conflict leads us in different directions from those pursued by Festinger (cognitive dissonance) and Abelson (cognitive imbalance). We are interested primarily in conflicts arising out of the denotative content rather than the affective tone of beliefs or thoughts and also in the relations between such conflicts and the pursuit of knowledge.

Hewson and Hewson (1984) used conceptual conflict rather than cognitive conflict because they intended to focus on conceptual problems in science learning. Like these examples, researchers chose a word according to their research concerns (for examples, conceptions, schema, function in cognitive development etc). Those are the reason why diverse words exist when explaining cognitive conflict situation.

In some literature, we could find few definitions of cognitive conflict as follows:

> Cognitive conflict is "awareness of a momentary disequilibrium" in the system of schemas (Mischel, 1971).
> In a social sense, cognitive conflict generally means some perceived contradiction between the subject's opinion and the opinions of others (Damon and Killen, 1982).
> Cognitive disequilibrium or conflict induced by awareness of contradictory discrepant information (Bodlakova, 1988).
> If a child eventually becomes aware of the fact that he holds two contradictory views about a situation and they both can not be true. This step is referred to as cognitive conflict or disequilibrium (Gredler, 1992).
> Cognitive conflict is created when one's expectations and predictions, based on one's current reasoning, are not conformed. It is disequilibrium (Wadsworth, 1996).
> Cognitive conflict is defined as a conflict between cognitive structure (i.e., an organized knowledge structure in the brain) and environment (i.e., a experiment, demonstration, peer's opinion, book, or something like that), or a conflict between conceptions in cognitive structure (Kwon, 1989).

As we can see, there are many words that have similar meaning to cognitive conflict. Each word has been used to explain a specific situation that is related to cognitive conflict because cognitive conflict is a broad concept and not well defined. This might make researchers confused about using the word cognitive conflict.

After integrating the many words that have been used to explain and define diverse cognitive conflict, we defined cognitive conflict. Cognitive conflict is a perceptual state where one notices the discrepancy between one's cognitive structure and environment (external information), or between the components of one's cognitive structure (i.e., one's conceptions, beliefs, sub-structures and so on which are in cognitive structure). In this definition, cognitive structure means, as Langfield-Smith (1994) said, any mental representation used to organize knowledge, beliefs, values, or other data whether hypothetical or neurological.

Cognitive conflict is strongly related to cognition. This is the difference between cognitive conflict and general conflict because conflict is aroused by incompatible motives and needs noted in the following definition:

> Conflict is a perceptual state involving the executive function of the organism where the immediate choices in the organism's repertoire, together with the outcome of these choices, are seen to involve incompatible motives and needs (Parker and Archer, 1994, p. 665).

The Types of Cognitive Conflict

Many researchers described how cognitive conflict is aroused. For instance, Strauss (1972) presented two kinds of cognitive conflict (his word, disequilibrium). One is external, adaptational disequilibrium by means of prediction-outcome conflict. The other is internal, organizational disequilibrium through structural mixture conflict.

Siegel (1975) described three different kinds of cognitive conflict (his word, discrepancy): (a) internal cognitive conflict (between two competing ideas); (b) external social conflict (between two external events or sources of information); and (c) internal-external conflict (between an internal and external event).

Kwon (1989) presented three types of cognitive conflict. He thought Piagetian cognitive disequilibrium was a kind of cognitive conflict between one's cognitive structure and environment. Using Hashweh's (1986) analysis, Kwon also considered metacognitive conflict as

other cognitive conflict that is a conflict between cognitive schemata. This cognitive conflict would be aroused when one might examine his/her own cognition without contacting his environment. Even in the Piagetian's disequilibria concept, there is the similar meaning to this kind of cognitive conflict; Hashweh made its concept clear.

In addition to these two kinds of cognitive conflicts, Kwon (1989) suggested the third kind of cognitive conflict. This kind of cognitive conflict can be aroused when a new conception, which might be scientific conception recently learned, is not compatible with an individual's past experience and/or the familiar with his/her old conceptions. Figure 1 shows Kwon's three kinds of cognitive conflict.

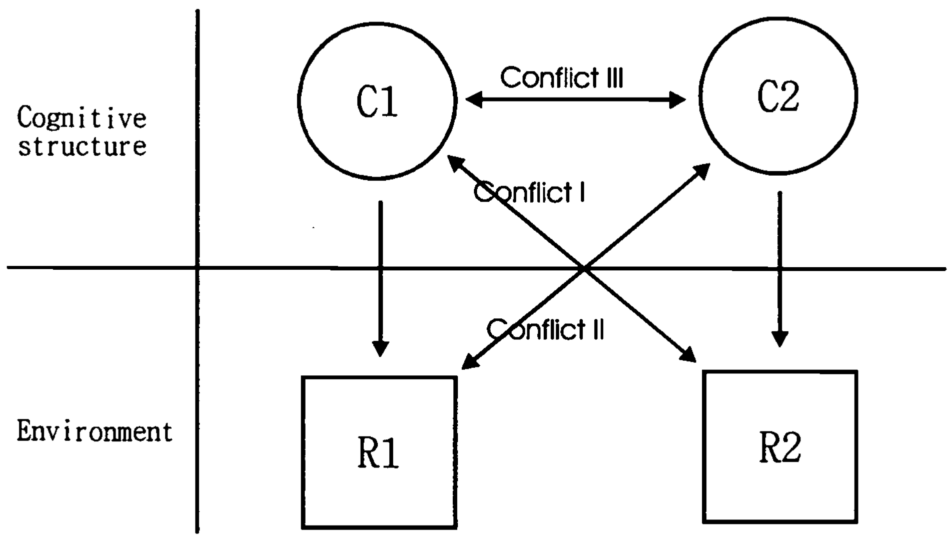

Figure 1. Kwon's cognitive conflicts model (Kwon, 1989)

This diagram is a modified version of Hashweh's original diagram (Hashweh, 1986). Kwon (1989) explained three kinds of cognitive conflict as follows:

> The upper part represents cognitive structure and lower part represents environment. For science instruction, a cognitive structure can be replace by scientific conceptions. C1 represents students' preconception or misconception. In a classroom situation it would be mostly a misconception. C2 represents a scientific conception to be learned. R1 represents environment that could be well

explained by C1, while R2 is any environment explained only by C2. R1 and R2 do not represent only one single external phenomenon. It represents the whole bunch of observations and stimuli from one's environment.

In this diagram, cognitive conflict by Piaget is conflict between C1 and R2 (Type I), cognitive conflict by Hashweh is a conflict between C1 and C2 (Type III). However, in the diagram one may easily recognize another kind of cognitive conflict between C2 and R1. Kwon proposed this as another kind of cognitive conflict (Type II). One may argue that this is just the Type I cognitive conflict. It may be correct, but for instructional purpose, to categorize this as a different conflict would be meaningful. Since Type I and Type II are all the cognitive conflicts between a cognitive structure and environment, the two cognitive conflicts could be categorized as the same kind. Under such a real situation as a teacher designs a new instruction, however, the two types of cognitive conflicts will function very differently in the preparation of instructional materials and in time allocation of activities. Therefore, to categorize the Type II as an independent type of cognitive conflict is meaningful.

When we think about the types of cognitive conflict, this diagram would be useful because of its simplicity. But from our interpretation of cognitive conflict, C1 and C2 should be not only pre/new conceptions which one learned in course of time but also beliefs, sub-structures, total structure, or something that is in cognitive structure, as we mentioned in the definition of cognitive conflict.

The Signs of Cognitive Conflict

Literature Review

Many researchers have tried to observe cognitive conflict and found diverse signs of it. For example, Miller (1944) observed hesitancy, tension, vacillation, and complete blocking in the cognitive conflict situation. Berlyne (1960) explained conceptual conflict had something like these: doubt, perplexity, contradiction, conceptual incongruity, confusion, and irrelevance. Berlyne (1960, 1970) thought the children's degree of uncertainty (about anomalous information) as the major sign (indicator) of the degree of their cognitive conflict (his word, conceptual conflict). He measured cognitive conflict by subjective uncertainty (provided by the children themselves) and response latency. Smedslund (1961) found hesitation (reaction time), looking back and forth, uneasiness, and tension as children were in cognitive conflict situation. Zimmerman and Blom (1983) measured students' cognitive conflict by observing the degree of

uncertainty, and response latency with using similar method to Berlyne's. Movshovitz-Hadar and Hadass (1990) found students' expressions in a state of a cognitive conflict from videotaped discussions. They said students showed expressions of curiosity arousal and expressions of an inner drive to resolve, as well as expressions of frustration, expressions of satisfaction with coping with inability to proceed, and expressions of contentment with feeling self-confident about a shaky state.

In summary, many researchers found many signs of cognitive conflict that could be observable and they used these signs as the indicators of the degree of cognitive conflict. According to these literatures, we could infer the psychological constructs of cognitive conflict. For instance, uncertainty, doubt, perplexity, contradiction, conceptual incongruity, irrelevance, being incredible are the signs of cognitive conflict when one recognizes anomaly that is contradict to one's expectation. So recognition of anomaly would be one construct of cognitive conflict. As another signs of cognitive conflict, to hesitate to response and/or to look back and forth are the behaviors when one tries not only to solve the conflict but also to decide to continue to do or not. In the one's internal state, one reappraises the conflict situation. So reappraising cognitive conflict situation is another construct of cognitive conflict.

Based on Anderson and Bourke (2000)'s affective area classification, we classified many affective signs of cognitive conflict into interest and anxiety. For instance, expressing curiosity arousal are the signs of cognitive conflict as a construct of it; interest. Tension, uneasiness, and frustration are the signs of cognitive conflict as a construct of it; anxiety. After all, there are four psychological constructs in cognitive conflict. Those are recognition of anomaly, reappraisal of cognitive conflict situation, interest, and anxiety.

Analyzing the Protocols of Previous Research

We analyzed protocols of the two previous research (Lee, 1990; Lee, 1998) where the researchers presented anomalous situations (i.e., demonstrations that were not incompatible with students' prediction) to students and observed their responses.

From these analyses, we found some verbal and nonverbal signs of cognitive conflict. According to the four constructs of cognitive conflict, we classified the signs as follows:

Recognition of Anomaly

When students recognized that their predictions were not consistent with the result of demonstration, they asked a question, wondered and muttered the result to themselves, or said the result was strange:

"Umm ... (rub one's chin).. Why does it?"
"Oh! It is same (height)."
(With a deep sigh) "it is strange."
"I cannot understand; it is strange"
(Looks the teacher with a amazing look)

Interest

After seeing the anomalous result, students expressed their interests by laughing or looked to be curious to know it:

(Laughs)
(A curious look)

Anxiety

In this case, we could find the verbal statements of students when they watched the anomalous result. They confessed it was difficult to solve the conflict problem by them.

"Ah! I know nothing about it."
"I fell into confusion."
"Ah! I have a headache about that (problem)."
"I cannot understand why the net force is zero. Even though it seems to be 2 N, I think the statement in the card is very like too. So I am troubled by the problem."

Reappraisal of Cognitive Conflict Situation (Hesitation to Response)

When students watched the anomalous result, many of them reserved their judgments that the problem was solved or not. A student did not move, and thought about the result for a long time. Another one looked at the experiment set closely and repeated thoughts.

> "I cannot explain the result well but...."
> "Centrifugal force? Inertial force? Centripetal force?" (With grumble to oneself, trying to understand the problem)

The Cognitive Conflict Process Model

The cognitive conflict process model was developed to explain the cognitive conflict when a student is confronted with an anomalous situation that is incompatible with his/her preconception in learning science. This model has three stages (see Figure 2): preliminary stage, conflict stage, and resolution stage.

The preliminary stage is the stage prior to cognitive conflict and includes the process of believing his/her preexisting conceptions and accepting anomalous situations as genuine (i.e., experimental results obtained by a teacher). In this model, cognitive conflict process is defined as after a learner (1) recognizes an anomalous situation, (2) expresses interest or anxiety in resolving the cognitive conflict, and (3) engages in cognitive reappraisal of the situation. For instance, when a learner recognizes that a situation is incongruous with his or her conceptions, he or she should be interested in and/or anxious about this situation.

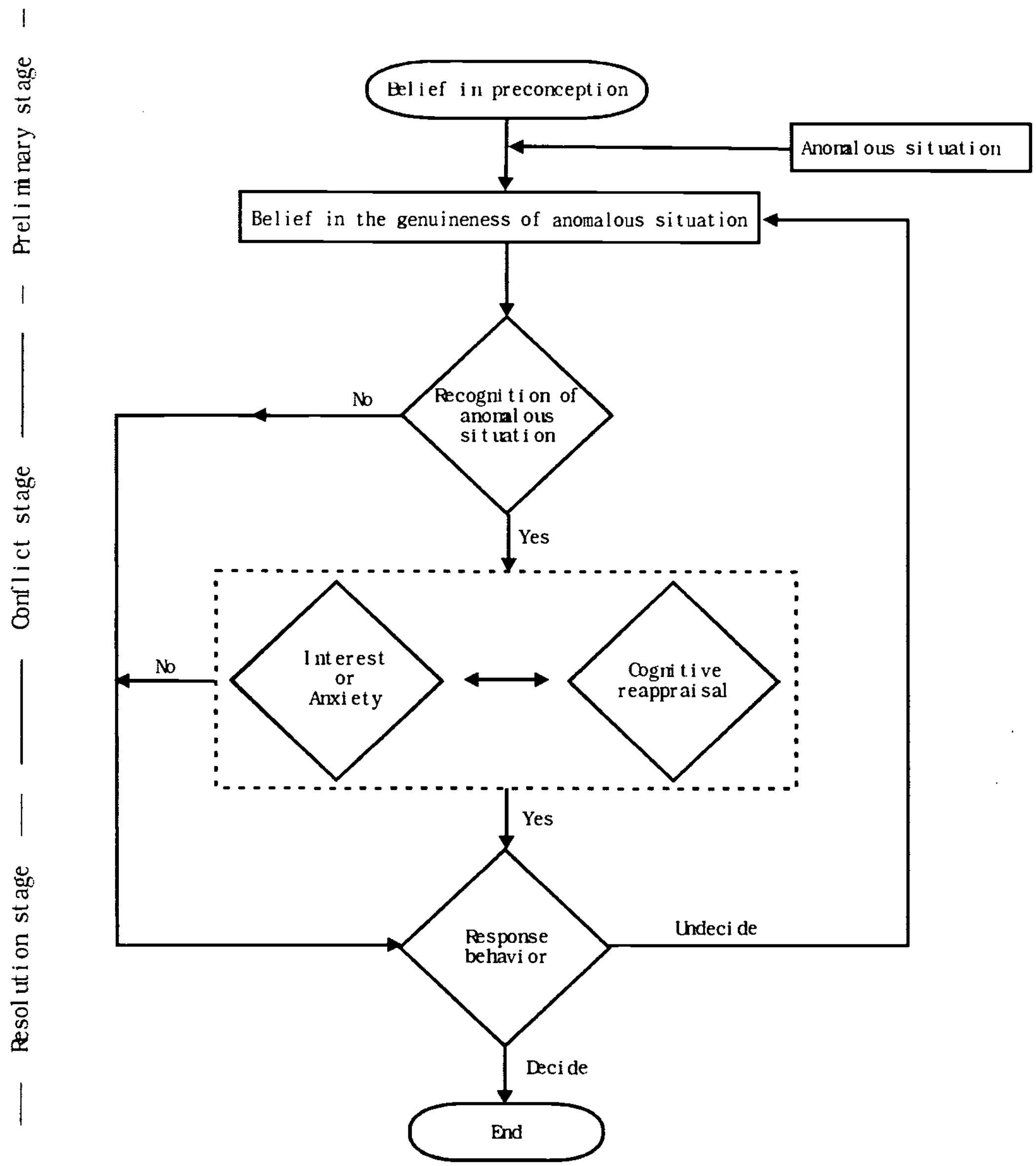

Figure 2. Cognitive conflict process model

After these stages or simultaneously with these, he/she would reappraise his/her cognitive conflict situation in order to resolve it or just to quit it. In Movshovitz-Hadar and Hadass (1990), we found some examples of cognitive conflict process:

A student recognized anomaly and felt interest and anxiety simultaneously: (in a state of cognitive conflict) "It (the result of demonstration) is kind of a shock, it's fun… no…, it's…, mind stretching"

A student felt anxiety, but after reassessing his/her cognitive conflicts, he/she escaped cognitive conflict situation by solving the problem:

"I was threatened in the beginning and controlled it. Then I was able to start thinking and worked it out."

A student escaped his/her cognitive conflict situation by giving up to solve the problem:

"I was helpless. I could not wait to hear the solution."

This model supposes that four components of cognitive conflict are the psychological constructs of cognitive conflict: recognition of anomalous situation, interest, anxiety, and cognitive reappraisal. In terms of the components of cognitive conflict, we can understand why cognitive conflict has the potential for producing either highly constructive or highly destructive outcomes.

For example, if a student does not recognize the anomaly, ignores it, or he/she does not like to be in conflict state, then the cognitive conflict in this situation might be negligible. And if a student feels bad (like being frustrated or being threatened) instead of being interested, his/her cognitive conflict might be destructive one. Constructive cognitive conflict could be aroused when a student recognizes anomaly clearly, experiences strong interest and/or appropriates anxiety, and reappraises cognitive conflict situation deeply. But if a student would not recognize the anomaly, ignore it, feel bad feeling (like frustration, being threatened) instead of interesting, and/or he or she would not like to be in conflict state, then the cognitive conflict in this situation might be negligible one or sometimes, destructive one.

In the resolution stage, a learner will try to resolve cognitive conflict in any way. The results of resolving this conflict will be expressed as an external response behavior. Response behaviors include those suggested by Chinn and Brewer (1998) such as ignoring, rejection, uncertainty, exclusion, abeyance, reinterpretation, peripheral theory change and theory change, and the knowledge-process activities suggested by Chann, Burtis and Bereiter (1997) such as sub-assimilation, direct assimilation, surface-constructive, implicit knowledge building and explicit knowledge building.

This model contains two assumptions: (1) the student's diverse characteristics (metacognition, learning motivation etc.) will affect the process of cognitive conflict. And (2) the components of the cognitive conflict will strongly affect the response behavior.

In our recent research (Kwon, Park, Kim, Lee, Lee, 2000), we investigated the relationship between cognitive conflict and students' response types. From students' interviews in this research, we found some examples of cognitive conflict process.

The participants were four students, tenth grade from high school in Korea. In the beginning of this research, we developed demonstration kits and preconception test on mechanics and electric circuit concept. Before the interview, four students were pretested on those concepts. Each student was individually interviewed. Based on the result of students' preconception tests, we presented the demonstrations that would be anomalous situations to each student. After this, we asked them to express their thoughts and feelings about this situation. Then, we gave them the cards (see Figure 3) that express the main signs of cognitive conflict: recognition of anomaly, reappraisal of cognitive conflict situation (hesitation to response), interest, and anxiety. We asked them to arrange the cards according to the order they thought and felt them in the cognitive conflict situation and to say their other thoughts and feelings that are not expressed in the cards.

Recognition of anomaly

- When I saw the result, I had a doubt about the reasons.
- When I saw the result, I was surprised at it.
- The difference between the result and my expectation made me feel strange.

Interest

- The result of experiment is interesting.
- Since I saw the result, I have been curious.
- The result of experiment attracts my attention.

Anxiety

- The result of the experiment confuses me.
- Since I can't solve the problem, I am in agony.
- As I can't understand the reason for the result, I feel depressed.

Reappraisal of cognitive conflict situation

- I would like to ascertain whether my idea is incorrect or not.
- I need to think about the reason for the result a little longer.
- I need to find a proper base of explaining the result.

Figure 3. Four cards

The following excerpt illustrates the portion of the dialogue in the interview with student 1.

Interviewer: (presents a demonstration to student 1)
Student 1: (looks at the demonstration kit and the answer sheet by turning and thinking for a while)
Interviewer: "Could you say now your feelings or thoughts?"
Student 1: "It is little short of a miracle, and I feel futility. I would like to know the reason for the result."
Interviewer: "I made four cards which include some sort of feelings and thoughts about this situation. Please arrange these cards, reflecting on your thoughts and feelings that were experienced as time went by."
Student 1: (arranges the cards)
Interviewer: "Do you have any other feelings or thoughts about the result except these (which were mentioned in the cards)?"
Student 1: "No."
Interviewer: "Do you think the result of this demonstration is right?"
Student 1: "Yes, because it is experimental result."
Interviewer: "Could you explain the result?"
Student 1: "I do not know. I saw the result for the first time."
(Talking to oneself) "Is it related with the principle of a lever?"

After watching the demonstration that was an anomalous situation to student 1, the students recognized the demonstration as an anomalous result. He felt futility as well as showed curiosity

to know the reason. Until the end of the interview, he tried to resolve his cognitive conflict. In result, student 1 experienced cognitive conflict such as the process that was proposed in the cognitive conflict process model.

Conclusion and Implication

Based upon this study, the following conclusions and implications can be drawn:

- Cognitive conflict is a perceptual state where one notices the discrepancy between one's cognitive structure and environment (external information), or between the components of one's cognitive structure (i.e., one's conceptions, beliefs, sub-structures and so on which are in cognitive structure).
- There are four psychological constructs of cognitive conflict: recognition of anomaly, interest, anxiety, and reappraisal of cognitive conflict situation.
- Cognitive conflict has constructive, destructive, or meaningless potentials. This is strongly related to how students experience cognitive conflict. By checking the signs of cognitive conflict, we could see the potential of cognitive conflict.
- When a teacher tries to use anomalous phenomena to foster conceptual change, he/she could use the model of cognitive conflict process to anticipate how students might experience cognitive conflict. This could help teachers to let their students experience meaningful cognitive conflict.
- In the further research, the cognitive conflict process model should be tested more extensively. We should have enough evidences to answer the questions; when, where, about what, and how our students experience cognitive conflict.

- In addition, we should study how we can make the most of cognitive conflict in our classes. As Johnson and Johnson (1979) said, managing cognitive conflict is very important. However there is little strategy to manage cognitive conflict. Based on our study, further research could focus on the problem of managing cognitive conflict.

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SCIENCE AND LANGUAGE LINKS

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Problem Statement and Background

Traditionally the focus of elementary education has been on language arts instruction and not enough on science education. The problem comes in when the science program is left by the wayside. Fitch and Fisher, in 1979, performed a survey in the Illinois area on what the schools were teaching. After examining returned surveys they concluded that science teaching lagged behind other subjects in a majority of schools in the Illinois area. Part of these findings can be attributed to limited teacher science knowledge, time, inadequate equipment and textbooks. Some current research also shows similar trends - that bulk of the time is spent on language arts instruction and not enough on science at the elementary level (Akerson & Flanagan, in press; Cunningham & Allington, 1999; Stefanich, 1992). Contributing factors to inadequate science teaching in these citations include limited science knowledge, inadequate equipment and textbooks.

Jarrett (1999) concluded that a majority of pre-service teachers at a Southern university were ill-prepared to effectively teach science. She performed the study over a three year period and found that limited experience with science was a determining factor that caused many pre-service teachers to shy away from effectively teaching science during their in-service. Personal experience, as a substitute in a large Eastern Washington school district, has also demonstrated that science instruction is limited at the elementary level. Science instruction seemed to be a small and isolated part of the day in

most of the classrooms observed. In a few classrooms though, science instruction did share a larger and integral part of classroom instruction.

Science is an ever changing field. If elementary science instruction is based on learning facts using old texts then the information taught may by outdated. A textbook transmission type approach to teaching science with little 'hands on' and 'minds on' inquiry and experimentation limits effectiveness of science instruction. Conversely, science learning that is composed of manipulating "cute" objects, plants, and animals with little debriefing and discussion also has limited effectiveness (Glynn, 1994). Effective science instruction requires a balance of 'hands on' manipulation, debriefing time and use of language arts skills. This is the focus of the research.

With increased technological advances in our world today, an adequate science background or 'scientific literacy' is almost essential to get ahead. An extensive science background isn't critical, but it is advantageous to be scientifically literate. For the lay person, newspapers, educational shows and magazines are good sources for cutting edge discoveries and current events. Scientific literacy enables us to understand, for example, the basics of a treatment that the hospital performs or it can help us to know what happens to all the garbage that is sent to the dump. Understanding options to medical treatments can help one make an informed decision. Knowing what happens to garbage that is sent to the dump may motivate reduction in waste by recycling and buying recyclable materials. Additional benefits of scientific literacy include preparation for higher level science courses in middle and high school and can build curiosity. Our modern, industrialized society relies heavily on scientific advances which drives the

economy. Some of these include Teflon, which has various applications; The microwave oven- a spin-off of the space program and various forms of synthetic materials that are essential to the function various systems such as an automobile engine.

A Solution: Integration of Science and Language Arts

The scientific inquiry process is a seemingly systematic method scientific investigators use to research discrepancies. A question arises that allows a researcher to formulate a hypothesis. A researcher then proceeds to answer the question or questions by setting up an experimental design. A sample question is "Do marigolds grow best in shade, full sunlight or half sunlight?" An experimental design allows the researcher to have a plan to help solve the question or questions. The researcher also repeats her tests to gain validity and to observe trends in the data. During the experimental process, the researcher continues to take down data and eventually brings the inquiry to a close. At the conclusion of the inquiry, the researcher processes the data and formulates sense from it. Trends are noted and eventually the findings are published-- anywhere from class work to an international journal. Figure 1 shows one possible flow of the scientific inquiry process.

Figure 1: Science inquiry flow (Adapted from Casteel & Isom, 1994)

Science inquiry process

1. Formulation of a Question
2. Hypothesizing
3. Setting up inquiry design
4. Experimentation
5. Gathering/organizing data
6. Analyzing results
7. Drawing conclusions
8. Report findings

Sometimes a researcher discovers something different than what he has originally planned. The scientific inquiry process is a fluid way of examining a problem. This process does not always occur in a linear fashion. This is illustrated by scientific advances which are gained from "accidents". An example is the revelation of the medical uses of penicillin which was derived from bread mold. This was discovered by Alexander Fleming a notable physician of his time. This "small" accident was a medical breakthrough and in turn helped modern society flourish and grow. In a sense Mr. Fleming found an answer, formulated a hypothesis and then worked towards an explanation of that answer.

Writing, reading, prediction, creative and critical thinking are integral processes in scientific research and inquiry. Scientists need to communicate both verbally and in writing to show others what they are doing. Language arts skills are critical in making predictions, chronicling discoveries and communicating findings. Science is not only formal research performed in a lab at a large company or in space, it is also backyard discovery. It can be a child looking under rocks to discover what is there. It can be a student watching ants in an ant farm in a classroom or a mechanic trying to figure out how to make a car run. It can be police detectives working to solve a crime and it also can be a young woman's drive to discover aspects of dolphin behavior. In all these circumstances, language arts are an integral part of the discovery and problem solving process. Also in all of these cases, predicting and making inferences play a major role in guiding inquiry.

The scientific inquiry process has parallels to the literacy process (Akerson & Flanagan, 1999; Casteel & Isom, 1994; Dickinson & Young, 1998). Both processes are a discovery method of inquiry beginning with an idea or question and ending with "publication" or reporting of findings. Several steps are involved to organize the seemingly random process of discovery which will eventually lead to a solution to a research question or a "publication". It is evident that science and literacy in some ways are reciprocal processes. Figure 2 illustrates this concept:

Figure 2: Reciprocal processes of science inquiry and literacy (Casteel & Isom, 1994)

Science inquiry process	Literacy process
Questioning	Purpose setting
I	I
Hypothesizing	Predicting
I	I
Setting up inquiry design	Organizing ideas
I	I
Experimentation	Constructing/composing
I	I
Gathering/organizing data	Evaluating/revising
I	I
Analyzing results	Editing
I	I
Drawing conclusions	Conclusions
I	I
Report findings	Communicating/publishing

It would be beneficial to teach in a way that accesses both processes to build scientific and language arts proficiency at the elementary level. Integrating science and language arts at the elementary level has benefits which include further developing both

science and language arts skills, allowing science learning a more important role in the elementary curriculum, and further engaging students in learning. (Akerson, 1999 & Flanagan; Cunningham & Allington, 1999; Romance, 1992). Effective science instruction requires more than a text based approach of learning facts or manipulating 'cute' things. A "minds on" inquiry based approach using skills such as questioning, predicting and experimentation is a more effective way of teaching science.

Increasing the depth of science and literacy teaching helps to meet the standards devised by the American Association for the Advancement of Science (AAAS) which states that science learning is critical in that the standards of the national benchmarks promotes...

> ...literacy in science, mathematics, and technology in order to help people live interesting, responsible and productive lives. In a culture increasingly pervaded by science mathematics, and technology, science literacy requires understandings and habits of mind that enable citizens to grasp what those enterprises are up to, to make sense of how the natural and designed worlds work, to think critically and independently, to recognize and weigh alternative explanations of event and design trade-offs, and to deal sensibly with problems that involve evidence, numbers, patterns, logical arguments, and uncertainties. (AAAS, 1993)

In conclusion, science teaching in many elementary schools is inadequate. These factors include teacher confidence in science, inadequate supplies, resources and time. Having an adequate scientific background is advantageous in our modern world. Benefits of scientific literacy include understanding basics of technology and prepares one for higher level science related courses. Integrating science and language arts at the elementary level also helps one have an advantage in a technologically advanced society and more effectively meets learning requirements formulated by the national and state

benchmarks. It seems clear that using science and language arts in complement with each other at the elementary level has multiple benefits as outlined. The next several sections will discuss a research design that may help to develop science inquiry and language arts skills concurrently in elementary students.

Purpose

One way of solving some of the problems presented and teaching in a way that access both science and language arts skills is through science inquiry. Effective science inquiry requires the use of language arts skills. These skills include organizing, creative thinking, discussion and writing. The first objective of this research is to discover ways to use the scientific inquiry process to develop language arts skills such as writing, predicting and making inferences. The second objective is to use language arts to develop science inquiry skills. Thirdly, enable students to understand that science plays an integral role in our society which may increase interest in science. One way to achieve these objectives is to teach lessons that pertain to the immediate environment of the student. An example can be learning about the sagebrush steppe ecosystem which is the predominant environment of the Mid-Columbia Basin. The following are the research questions posed by this teacher researcher.

Research Questions

- Can organized inquiry further develop students' writing, prediction and inferencing skills?
- Can the use of language arts skills aid science inquiry skills?
- Can relevant and organized inquiry change students attitudes towards science?

Research Population

The research environment consisted of a mainstream fourth grade classroom in an elementary school which resides in a large Southeastern Washington school district. The school is located in an upper middle class neighborhood. Several students received extra help from pullout programs and in class aids. Ten students were chosen for data collection by the field specialist and they ranged low to high academically. The ten students consisted of five males and five females. Lessons were taught to all students to minimize segregation in the class. Further into the research period, six out of the ten students were chosen for continual detailed data collection. This was done because of time factors in the classroom. Again the students were split evenly between sexes and consisted of a range from low to high academically. Amount of time spent in the classroom was approximately three days a week. One hour in the afternoon was apportioned to science.

The field specialist's teaching methods consisted of themed units. Science textbooks were used as an accessory to teaching. The students used science journals to take notes with and write down observations. The journals allowed the field specialist to assess students. This research started at the beginning of a habitat unit.

Research Design

An investigative worksheet was used as the main method of data collection. This worksheet is found in Appendix A and is adapted from the Puyallup School District format (1999 Washington Science Teacher's Association Conference). This format is included in Appendix B. The worksheet was adapted for each investigative exercise.

Appendix C provides an explanation of the various parts of the investigative worksheet. This worksheet provides prompts for the student to perform an investigation in which to answer questions that were postulated from an observation of a discrepant event. A discrepant event requires further study and research to seek an explanation. The discrepant events are outlined in Appendix F. Prompts were used to guide inquiry throughout the exercises. Through time and repetition, it is hypothesized that students will gain confidence in inquiry and eventually become more independent in investigations. It is also believed that students can generate some of their own questions in finding a solution to a problem. In turn, these questions can guide their own inquiry to seek a plausible explanation of an event.

Some discrepant events may have an explanation that is beyond the scope of students' understanding. The main focus is not discovering the exact explanation of a discrepant event, but it is on the process itself and the concurrent development of language arts skills.

The gradual release of responsibility model was used as a backbone to the teaching of science lessons over the nine weeks. This model dictates that all responsibility of teaching falls upon the teacher in the beginning of an educational set. The teacher begins by presenting material while students take in the information. Gradually, responsibility of the learning falls upon the student. The teacher eventually becomes the facilitator by setting up a problem set and acts as a guide for the student in seeking the solution (Reutzel & Cooter, 1999). The proposed research flow follows the gradual release model and is found in Appendix E.

Procedures

The following are the data collection methods. These methods are used to provide multiple sources of data. Multiple sources of data are used to verify and triangulate trends in science inquiry and language arts development.

Investigative Worksheets

The investigative worksheets chronicled each experiment/observation done in class. The master form is found in Appendix A. The worksheets were adapted for each lesson. It served as a measuring tool for the teacher researcher to follow student cognition of concepts, understanding of the scientific inquiry process, observe student generated questions and gauge continual development of language arts skills. A rubric, found in Appendix D, was developed to assess the investigative worksheets and inquiry process.

Pre and Post Student Science Survey

Surveys were given before and after the research and used mainly to measure students' attitudes toward science and science learning. It is also used to validate findings with the other data sources. Refer to Appendices G and H for the pre and post science surveys respectively.

Audio Tape Interviews

Interviews were conducted throughout the research project to probe deeper for student cognition of concepts. In depth audio interviews were performed with the 6 students in the research pool. Interviews were transcribed and analyzed.

Field Specialist Observations

Field Specialist observations helped to verify any trends found in the data.

Intervention/Classroom Curriculum

To minimize impact to the classroom flow, inquiry exercises were implemented in conjunction with the classroom curriculum. The field specialist and the teacher-researcher co-taught the lessons, helped with small group instruction and offered individual help. Instruction consisted of an orientation period which the student researcher taught a way of performing scientific inquiry using the worksheet format. Students used investigative worksheets as a guide in the inquiry process. The first several weeks, an investigative problem solving process was modeled with the students. The weeks ensuing, students were gradually allowed to carry out investigations on their own with the structured worksheets. Hands on activities allowed students to experiment and discover. Prompts aided students in the investigative exercises. Questions in the conclusions ascertained student learning. The following is a brief synopsis of the themed units. An example of the progression of one student's inquiry worksheets are included in Appendix I.

The Animal Unit

The research period started at the end of this unit. The students transitioned into the water and land unit by learning about animal habitats in and around aquatic environments.

Habitat Transition

Several lessons taught students about the presence of animals through evidence left in an area. Evidence includes but are not limited to tracks, droppings, claw and teeth marks. These several lessons focused on deducing animal type and behavior by means of track imprints.

Land and Water Unit

Several lessons transitioned the class in predicting what types of animals lived in or near an aquatic habitat. One lesson had students predict what might live in a photograph of an environment. Students were asked to defend their reasons.

Additional lessons transitioned students to the importance of the water cycle. Students learned about the water cycle and its importance in the earth ecosystem. Students built a model of the water cycle to emphasize this concept. Several more lessons transitioned the class to a controversial local event.

The Snake River dam issue is this controversial local event. This highly charged local issue is focused on whether or not to breach (take out) the four lower Snake River hydroelectric dams in order to preserve salmon runs. Several inquiry based activities were used to test problem solving abilities. One of these activities asked students to design a solution to a flash flooding situation on an imaginary river near an imaginary town. Students were assessed on abilities to incorporate learned and outside knowledge, teamwork, organization, innovative thinking and cause and effect relationships.

Open type questions were asked to allow the student to delve deeper in the inquiry process. A sample question included: "The town experiences occasional flash floods.

The town council has asked your company to find a solution to this problem. Think also of the environmental impacts of this solution. What will your company do to solve this problem?" The students devised a plan for inquiring this question using the investigative worksheet.

During the land and water unit, at approximately week seven, the structure of the worksheets and guidance was decreased to test independent inquiry skills and confidence. These exercises included designing a safer dam/turbine for fish passage and an investigation into what happens to milk over a five day period during week nine. The milk observation were done as an accessory to Science Week. This week included the parents performing science activities with the students. The theme of science week was health and the human body. In the milk observation exercise, five bottles of milk were given different treatments. It was the job of the student to predict, observe and record changes in the milk, then make conclusions on those changes.

Results

Data Analysis

Names of the students have been changed to preserve anonymity. Worksheet progression from Sandy is included in Appendix I and analyzed in part III of this section. General trends are discussed for the other five students in the research pool. Responses received on the pre and post survey for the whole class are summarized and tabulated in sections I and IV.

A portion of the data analysis occurred through rubric assessment of the investigative worksheets. The rubric is on a four point scale. The rankings are developed

and included in Appendix D. Each investigative exercise in the research pool was ranked by comparing it to the rubric.

Whole group, small group discussion, field specialist observations, and transcribed audio taped interviews were also considered in assessing student work. Trends for the research pool are included in part II of this section. The results are discussed in the following sections:

I. Whole Class Pre Science Survey

II. Research Pool Trends

III. Detailed Analysis- Sandy's Work

IV. Whole Class Post Science Survey

<u>I. Pre Research Science Survey- Whole Class</u>

The survey consisted of 2 parts. The first part involved short answer questions and the second part asked the students to rank Likert statements to best describe themselves. The Likert scale ranged from "strongly agree" to "strongly disagree." Refer to Appendix G.

<u>General Trends- Pre Survey</u>

The general finding on the pre survey revealed that a majority of the students tended to have a positive attitude toward science. Almost all students showed a tendency toward inquiry when faced with an investigative type question-- questions #2 and #5. The most notable finding appeared to be the description of the scientist. The students who described the stereotypical view of a scientist included a white coat, safety glasses, gloves and being very smart. Even though a majority of the students enjoyed science and

had a positive view towards the subject, most did not make the connection that a scientist could be the non stereotypical view. The same question was asked on the post survey to show a comparison. The results of this question was notable between pre and post surveys. This finding will be discussed further. Table 1 and 2 summarizes the pre science survey responses. 25 pre surveys were received.

Table1:

Summary of short answer questions in part I of survey. n = 25

Question #	Student responses
1. Circle your favorite subject.	• Four of 25 students circled science as their favorite subject. • Six students circled more than one subject- science included in the set.
2. What do you do if your clock breaks? Throw it away or try to fix it?	• 18 of 25 students said they would try to fix the clock • Two students said they would ask for help. • The remaining five students circled both responses.
3. What do scientists do?	Responses include: • "Experiment things" • "Scientists find answers" • "Creates things and figures things out" • "Discover things" • Most other responses were variations of these replies.
4. What do you think a scientist looks like? Write down a couple of words or draw a picture.	• 20 students responded by describing a scientist to have safety glasses, white lab coats, gloves and other protective gear. Many also mentioned that a scientist is very smart. • The remaining five students described a scientist to be a normal person or anyone.

5. What would you do if you saw something at the bottom of a puddle or tide pool?	• Three students mentioned that they would leave it alone. • The rest of the responses ranged from observing it, picking it up, or examining it.

Table 2:

Breakdown of students who agreed or disagreed with survey statements. n = 25

Statement #	Agree-Strongly Agree	Disagree-Strongly Disagree
1 You had a lot of science learning when...	12	13
2 Science is your favorite subject	13	12
3 You like to take things apart to see...	17	8
4 You like to read and write	18	7
5 You can be a scientist	15	10
6 Reading and writing are required to...	21	4
7 I have enjoyed learning science so far...	23	2
8 Science is important in our lives...	22	3
9 So far, I have learned a lot in science...	24	1
10 You like to explore	23	2

II. Research Subgroup Results:

Pattie, Sandy and Lacey (females) formed the high ability students. Chris (male) was perceived as having average ability in science. Patrick and Peter (males) were classified as low ability students. Possible trends will be discussed within each ability level. Audio tape interviews were conducted whenever possible. Each inquiry exercise

had different goals and expectations, thus not all criteria on the rubric were used in ranking each student inquiry exercise.

High Ability Students

Pre science survey

The three students from this group generally regarded science in a positive way. All indicated that they would try to fix something if it was broken which is question #2. These students showed investigative tendencies when asked to respond to question #5- "What would you do if you saw something at the bottom of a puddle or tide pool?" A response included "picking it up and examining it."

Lacey exclusively mentioned that a scientist "looks like a regular person." An interview revealed that her father worked at a large research laboratory. None indicated that they disliked science.

In Part II of the pre survey, the students showed generally positive inclinations toward science learning.

Investigative exercises

There was no notable change in rubric scores over the research period for the three students. Both Pattie and Sandy averaged a ranking of 3 on their investigative worksheets. This meant students had minimal spelling errors, demonstrated adequate understanding of cause and effect relationships and offered reasonable predictions based on observations. Lacey had an average ranking of 2. Her rubric ranking was lower due to incomplete worksheets, poor penmanship and numerous spelling errors. Lacey was able to express her ideas and learning with agility during audio interviews. She

verbalized creative solutions for various problems and exhibited good understanding on cause and effect relationships. She did not submit a proposal for making a dam safer for fish passage. In contrast, Sandy was not as verbally adept when interviewed.

Pattie's investigative worksheets showed clarity and exhibited good spelling. She offered reasonable predictions and recorded detailed observations of the events. She demonstrated understanding of concepts through answering most of the questions in the conclusionary sets. Audio interviews revealed good awareness of cause and effect relationships. She is also practical in her solutions. This is evident most in her Design a Safer Dam plan. Her design demonstrated basic understanding of the function of a dam. She also demonstrated the impacts of making modifications on a dam

Post science survey

There was no perceived change in overall attitudes towards science. Generally, the science surveys indicated positive tendencies toward science and science learning. None of the three students indicated that they disliked the subject. The three students gave a variety of responses on question 2, part 1 of the post survey which asked students what they learned. Some responses included ideas about water, dams and milk observations.

Pattie and Sandy both described the stereotypical view of a scientist in writing. Additional audio interviews revealed changed perceptions of a scientist. All offered positive comments when asked question #5 "What kinds of things did Mr. Liu do to help you in scientific investigations." These responses included "Helped me learn," and "Helped me understand." Part II of the post surveys remain largely unchanged.

Average Ability Student

Pre science survey

In depth interviews with Chris revealed that science was his second favorite subject. He offered some descriptive words which characterized the stereotypical view of a scientist. Responses to questions #2 and #5 showed tendencies toward investigations when faced with a problem. These include "I would try to fix it," on question #2 and "I would see what it is," on question #5. Responses on part II of the pre survey indicated a generally positive attitude towards science and science learning.

Investigative exercises

Rubric ranking averaged 3 for the investigative worksheets. This above average ranking was augmented by evidence such as clarity of writing, minimal errors in spelling and demonstration of learning in conclusion sets. Improvement in language arts skills was not noted. Predictions were logically connected to observations. Observations were clear and detailed. Audio interviews revealed that he was slower at organizing ideas verbally. He did not submit a Design a Safer Dam worksheet.

Post survey

The placement of science in his favorite subjects remained the same. He offered various ideas learned in writing and verbally on question #2 such as ideas about dams, salmon and watersheds. He also changed his view of a scientist from the pre survey mentioning that a scientist "didn't have to have white coats." He offered positive responses for question #5 such as "sometimes give us the answers if we were stumped..."

Part II of the post survey remained largely unchanged from the pre survey. He agreed that scientific investigations have more than one answer.

Low Ability Students

Pre science survey

In Peter's pre science survey, he circled science as his favorite subject. He mentioned that he would throw away a broken clock and would not investigate something in question #5. Responses to questions #2 and #5 may show a neutral or negative attitude toward inquiry. Patrick, in contrast, showed a tendency toward exploration in his response to questions #2 and #5. Both Patrick and Peter described the stereotypical view of the scientist. Both circled science as one of their favorite subjects on question #1. Responding to the statements on Part II of the survey, Peter agreed with all of the statements with the exception of concurring that reading and writing are required to learn science. When interviewed about this statement, he noted that he sometimes agreed and sometimes disagreed with this statement. Interviews revealed that Patrick did not like to read and write and disagreed that science is important in our lives today. Further interviews revealed that he was aware of technology and how it benefits the modern world.

Investigative exercises

Peter exhibited low writing and spelling ability. His penmanship and style of writing did not appear to improve over the two month period. There was no perceptible improvement in other language arts skills. Ranking of his investigative worksheets did not show an improvement in inquiry. Predictions were sometimes absent and

observations minimal. Responses to the questions in the conclusionary sets were short and did not show substantial evidence of learning. The rankings ranged between 1.5 to 2. He had some trouble expressing ideas verbally.

Patrick also had trouble with spelling and clarity of writing. Again, there was no perceptible change in clarity of writing or other language arts skills. Responses to questions in the conclusionary set were short, unreadable or offered little evidence of learning. In contrast, verbally, he articulated scientific concepts clearly. One example included him mentioning if a dam was breached, then it would flood his relatives house on the river. This example demonstrated his awareness of cause and effect relationships. He was also aware of the connections between in class learning and the outside world. Sometimes he offered and outlandish and illogical ideas in finding solutions to problems.

Post science survey

The post survey showed that Peter rushed through responding to the questions and statements. Poor penmanship and spelling errors can be attributed to his dislike of reading and writing. Additional evidence included him marking "disagree" on the statement "You like to read and write." All other statements were marked with either a strongly agree or agree. He believes that scientific investigations have more that one answer and held onto the stereotypical view of a scientist.

Patrick circled science as one of his favorite subjects. Interviews revealed that he liked the subject. He did not offer much in writing on what he learned in the past two months. Interviews revealed more ideas about the land and water unit and the Snake River dam issue. The interviews also revealed a changed view of the scientist. No

detectable change between the pre and post surveys on the Likert scale statements was noted.

III. Analysis of Sandy's Work

Inquiry worksheets from the Watersheds activity and the Design a Safer Dam are not available from her. Blank copies of both activities are included. The circled numbers in the upper right hand corners of the worksheets represents the rubric ranking.

Before 2/07/00

The teacher-researcher demonstrated the investigative worksheet with several whole class inquiry exercises. Students observed while the researcher performed several investigations.

2/07/2000

Tracks I: The teacher-researcher modeled an activity deciphering animal presence through track imprints with a small group. Sandy clearly duplicated the material presented on the investigation.

2/10/2000

Tracks II: Again, the teacher researcher performed the activity with the small group. Sandy succinctly recorded the data for each part of the worksheet while teacher-researcher dictated and performed the investigation with the group. Through group discussion, the way a rabbit made its tracks was discovered. Evidence of language usage included creative and critical thinking.

2/15/2000

Tracks III: This exercise focused on inferencing through available evidence. The researcher guided students through the investigative process. The procedures section of the worksheet was left blank. It was not an expectation for students to write them down. Students seemed at first confused by the presentation of the lesson. The researcher presented the evidence in steps which may have cause confusion. The lesson required three sets of inferences and three sets of observations. The lesson presented by the researcher did not include this procedure initially. The teacher-researcher adjusted the activity in mid-lesson thereby contributing to the confusion. The end result seemed to be positive as students appeared to be curious about exact answer. An exact answer was not possible because of limited evidence available in the illustrations of the markings- which may be animal tracks. The main objective was not deciphering what kind of animal made the tracks, but inferencing on what the tracks or marks could be doing. Sandy's worksheet demonstrated adequate understanding of the activity by offering logical predictions and conclusions.

2/17/2000

What Lives in This Habitat I and II: An investigation was modeled with the students in "What Lives in This Habitat I", then students grouped up to perform another investigation in "What Lives in This Habitat II". On part I, Sandy demonstrated adequate observation and listening by recording the data presented during the whole class lesson. She did not offer additional observations and conclusions other than what was presented. On part II, it was unclear what her contribution was in the group work. The group offered

a reasonable prediction (snowy owl) based on observations (snow covering, water and tall grass). The group also understood that more evidence was needed to know exactly what could live in the snow covered environment.

2/22/2000

Precious Water: Structured worksheets were used with students in this investigation with reduced guidance. Students learned about the availability of water on earth by a model. The materials and vocabulary sections were not emphasized. Sandy understood that water is a valuable resource in the earth ecosystem. She also recorded a reasonable amount of observations. The answers in the conclusion set demonstrated what she learned during the activity.

2/23/2000

Water and Land Model: Students individually filled out the worksheet while working in groups of 2 or 3. Sandy's predictions demonstrated a logical progression of a cause and effect relationship. Also included are all the materials and most of the vocabulary words presented during the presentation part of the lesson. Procedures are included, but not detailed enough to follow. Observations recorded are minimal. The responses included in the conclusion set demonstrated minimal learning.

2/28-2/29/2000

To Dam or Not to Dam: These couple of lessons focused on the Snake River dam issue. The lesson was somewhat complicated- in terms of directions and expectations. Most students seemed confused on the activity. The lesson involved each student having an assigned role- either pro dam or pro fish. The scenario had students discuss their

characters' viewpoint on the positive or negative effects of building a dam. This activity was confused with the Snake River dam issue. The Snake River issue is about the feasibility of breaching the four dams on the lower Snake River. Sandy's unfinished worksheet demonstrated her lack of understanding. Additional interviews revealed confusion about the activity. She was confused on whether her assigned role was pro dam or pro fish. This caused other students some distress too. Interview responses with her and other students revealed melding of the two issues together. It was difficult to sort out interview responses and whether if students were talking about the Snake River dam issue or the pro dam/fish activity.

3/9-3/10/2000

Flash Flood Control: Students allowed to work in groups with minimal guidance. A structured worksheet was provided. Sandy's group appeared to understand cause and effect relationships of building a dam to curb flooding. The group also understood that a monetary value is involved in building a dam and sought to raise support if a dam was to be built. Their plans did not address possible environmental impacts. The researcher asked Sandy's group about the environmental impact of their plans on a follow up interview but responses did not reveal anything notable.

3/13-3/15/2000

Watersheds: A paper model was used to learn about watershed. A worksheet from Sandy was not turned in. The students worked in groups of three or four. Her contribution to the activity was not recorded.

3/20-3/21/2000

The River: This activity explored pollution and its effects on river ecology. Because of the complexity of this activity, the field specialist lead the class in building a "river". Each student "owned" a piece of property (piece of paper) on a "river". Each piece of paper was connected forming a paper river. This activity was used to demonstrate accumulation of pollutants downriver. Each "property owner" contributed something to the river, thereby adding to the accumulants further down river. Sandy adequately demonstrated previous knowledge in the "What I know" section of the worksheet. The predictions did not make sense towards this activity saying "It will rot and finally evolve into water." It is unclear what her response refers to. A follow up interview was not conducted. The rest of the worksheet minimally demonstrated learning and investigation.

3/22-3/24/2000

Design a Safer Dam: Students individually designed a plan. A plan was not received from Sandy. Informal interviews with her revealed confusion on expectations. She had a difficult time drawing a cross section of a dam. In contrast some other students readily drew a cross section of a dam and offered design features to make it safer for fish passage. Sandy's unsubmitted proposal could demonstrate that she was not ready for more independent inquiry.

3/27-3/31

Milk observations: Students predicted, observed and concluded on what happened to milk samples over a five day period. Sandy offered one word predictions

during the first four days and also included most materials used in the activity. The first four days, short observations tended to show that she rushed through the describing each milk jar. The detailed descriptions in day five showed more careful observations. Her responses in the conclusion set demonstrated understanding of observations and making reasonable conclusions based on those observations. The increased structure and expectations of this activity may have contributed to her improved performance in science inquiry.

IV. Post Science Survey Changes- Whole Class

Several changes were made to the post science survey. These included the omission of questions #2 and #5. These were replaced with Question #2 "What did you learn when Mr. Liu helped Mrs. H teach science?- the main ideas (do not include materials learned when the Pacific Science Center was here or from parent helpers during Science Week.). Also Question #5- "What kinds of things did Mr. Liu do to help you in scientific investigations." 24 post surveys were received.

Several changes occurred on part 2. These included the omission of Statement #1. Statement #10- "Scientific investigations have one right answer" was added. Several of the statements were reworded. A neutral column was added to part 2.

General Trends- Post Survey of Whole Class

A notable decrease occurred in the amount of students who marked science as their favorite subject. Students who disagreed with this statement did not necessarily mean they disliked science and science learning. Follow-up interviews confirmed some of this discrepancy. An increase in students responding positively to "You like to take

things apart" could show an increase tendency toward scientific investigations. A small increase in students agreed that they could be scientists. There was no detectable change in the statement: "Reading and writing are required to learn science." The same trend was recorded for the number of students who responded to the statement "I have enjoyed science learning so far this year." This finding confirmed that the majority of students retained positive attitudes toward the subject. Again a majority of students believed that science is important in today's world. There was little change from the pre science survey. The remaining statements reveals a positive tendency towards science and science learning. The last statement "Scientific investigation have only one answer" on the post survey was not included on the pre survey. Results of this statement post survey demonstrates that a majority of students believe that there is more than one answer for the scientific investigations performed in class. Although some changes occurred within certain statements, overall student attitude towards science and science learning did not appear to shift dramatically over the two month period. Refer to table 3 for a summary of part one and table 4 for the summary of part two.

Table 3

Summary of student responses from part one. n = 24

Question #	Student Responses
1. Circle your favorite subject.	• Eight students chose science as their favorite subject. Six of these responses circled other subjects included. • 16 students chose other subjects as their favorite.
2. What did you learn when Mr. Liu helped Mrs. H teach science?	• Various responses ranged from footprints to the Snake River dam issue. Most of the responses were not very detailed. A hindering factor could be time in filling out

		the surveys as it was close to recess when students started the surveys.
3. What do scientists do?	•	Responses were similar to the pre-survey.
4. What do you think a scientist looks like?	•	19 students mentioned variations of the stereotypical view- white coat, safety glasses, gloves and etc. Three students described a regular person. These were the same students which indicated similar descriptions on their pre science surveys.
	•	Two students offered no descriptions with their illustrations.
	•	Trends between the pre and post survey are noted in the conclusions.
5. What kinds of things did Mr. Liu do to help you in scientific investigations?	•	19 students responded positively with comments such as "He helped us learn more," or "Helped me understand what we were doing."
	•	The remaining five students were neutral or less.

Table 4

Breakdown of students who agreed, disagreed or showed neutrality. n = 24

Statement #	Strongly Agree-Agree	Neutral	Strongly Disagree-Disagree
1. Science is your favorite subject.	7	2	15
2. You like to wonder how things work.	23		1
3. You like to read and write.	16	1	7
4. You can be a scientist.	18		6

5. Reading and writing are required to learn science	21		3
6. I have enjoyed science this year.	23		1
7. Science is important to us.	23	1	
8. I have learned a lot in science.	22	1	
9. You like to explore.	24		
10. Scientific investigations have one right answer	4	2	18

Conclusions

Outcomes

The outcomes will be discussed using the three research questions as the framework.

Can organized inquiry develop language arts skills such as writing, prediction and inferencing in fourth grade students?

Students did use language skills such as prediction, writing, and observation to perform inquiry. The inquiry worksheets provided a framework for the students to investigate a problem. No detectable trend in additional development of language arts skills was observed. As structure of the science inquiry activity decreased, it seemed that most students' language arts use and ability to perform a less structured inquiry also decreased. A majority of students did not appear to be ready for an increase in independent inquiry. Evidence included incomplete worksheets and a decrease in the

amount of submitted work. This was most evident during the Design a Safer Dam activity.

Some evidence of independent inquiry, innovative and creative thinking was observed within the research pool, but trends were unremarkable. Some students outside the pool also showed a remarkable amount of independent inquiry, innovative and creative thinking. One on one, small group and whole class discussion provided evidence of independent inquiry and creative thinking. Trends on innovative and creative thinking were not explored further for the rest of the class. It is unknown if the language arts skills of these students were further developed as a consequence of science inquiry.

The nine week research time established a foundation for additional creative thinking, independent investigations, concurrent development of language arts skills and science inquiry. Referring to the proposed research flow, Appendix E, most students remained in the low or no risk category on the envisioned outcomes. A couple of students showed some evidence on high risk taking in inquiry. It is believed that one of the reasons most students remained in the low or no risk category was attributed to decreasing structure of inquiry too soon.

Another reason is that it took time for the students to adjust to the methods of instruction presented by this researcher. Evidence of this included some student confusion on the investigative exercise expectations and clarity of directions. Unfinished worksheets were the main consequence in this adjustment period. In short, some adjustments needed to be made to maximize learning and decrease confusion. It is hypothesized that if research was continued some students may be able to perform simple

inquiries without the structure of the inquiry worksheets. In other words, students are given a problem set, then figure out the best solution with minimal guidance. A basic investigative framework would be provided for students to follow.

Can organized inquiry change students' attitudes towards science?

Some changes in attitudes towards science were recorded between the pre and post science surveys, student interviews and general observation. The most notable change occurred on the scientist descriptions, otherwise students were generally positive towards science.

All but one of the students in the research pool who described the stereotypical viewpoint of a scientist kept their view on the post surveys. Follow up interviews on the post surveys revealed a detectable trend in the description of the scientist within the research pool. This included all but one of the students revealing that scientists could be anyone or a normal person. Most of these students described the stereotypical view of a scientist on their pre science surveys. It is believed that if more students were interviewed, additional changed views could be revealed. Changes in the descriptions of the stereotypical scientist could have resulted from repetitive use of inquiry worksheets, making science relevant to the students by discussing local issues and the presence of the Pacific Science Center during the last week of the research period. The presenters from the Science Center emphasized to students that they could be scientists. The change in the view of the scientist could indicate an increase in positive attitudes toward science and an increased possibility that student will embrace science and technology. Students

may also realize the fact that a scientist doesn't have to be a genius type like Albert Einstein- but a regular person. It could even be themselves.

Can the use of language arts skills aid science inquiry skills?

Yes, students performed more organized inquiry. Some science inquiry and language arts skills observed include recording observations, making predictions, communicating findings, writing down materials needed in an investigation and making conclusions. While no noticeable change in these skills were observed over the two month period, students still learned material by using language arts skills in scientific inquiry. Field specialist observations concurred with this finding. Some students were readily able to talk about the concepts they learned. Some students mentioned that the worksheets and activities helped them learn the material.

On the post science survey, 18 of 24 students responded positively to question #5 "What kinds of things did Mr. Liu do to help you in scientific investigations." Some responses include: "helped us understand science," "helped me learn," "help us if when we were stuck," and "have us write about things." In depth audio interviews also revealed similar comments. A variety of learning modes- hands on inquiry, question and answer sessions, group and individual work seemed to help students. Differences between students' learning ability before the research time and during the research time were not explored. It is unclear whether cooperative skills improved over the research period.

Implications

Integration of Science and Language Arts

One of the benefits of integrating science and language includes developing science inquiry and language arts skills concurrently. It was unclear how further development of language arts and science inquiry skills occurred in this research. students did perform science inquiry and use language arts skills to perform science inquiry. Students organized their thoughts, predicted and found solutions to discrepant events. Field specialist comments showed that the structure offered by the investigative worksheets allowed engaged learning to take place. According to Glynn, 1994, students who performed hands on manipulation and discussed their findings retained the learned material more effectively than just manipulating "cute" objects and animals or learning from rote and transmission. This seemed to be confirmed during the research period. Field specialist observations also pointed toward hands on manipulation and discussion as an effective way of science instruction. Conclusively, instruction that uses various means- such as writing, debriefing, hands on inquiry and discussion is an effective way to teach science.

Making Science Relevant

Another benefit of integrating science and language arts is placing science learning higher in the elementary curriculum. The science content taught by this researcher was not detached from the world of the students. A majority of the lessons included materials relevant to the immediate area of the Mid-Columbia Basin. Some lessons included learning about the Columbia River watershed, issues surrounding the

Snake River dam breaching and animal habitats in the immediate area. The students seemed to be engaged in learning about their surroundings. Positive field specialist comments reflected the relevance of the teacher-researcher lessons. One of the benefits of scientific literacy includes learning better ways of interacting with the world around us. This aspect of scientific literacy was achieved during the research period.

Although no consistent trends of increased student curiosity of science learning were observed, some sporadic evidence of curiosity was noted. Evidence included some students staying in during recess asking questions and/or doing additional research in encyclopedias or other sources. It was not an expectation for students to perform outside research in earlier investigative exercises. Towards the end of the research period, using extra resources was an option for students to find solutions to a problem. Some evidence of using resources outside the class was noted during this period which included bringing in materials and parental advice.

Implementation of Science Inquiry

Investigative inquiries were kept as simple as possible. Most of the materials required in a specific exercise were readily available or could be obtained cheaply at stores in the immediate area. Some lessons required students to work in groups. This also minimized cost and preparation of supplies for the lessons. A science kit (Land and Water by Carolina Biological Company) was available for classroom use. Some lessons were taught using materials from the science kit. Accessory science education books were also used which have many relevant exercises that are easy to implement. Two examples include "Science Is..." by Susan Bozak and "Teaching Science to Children: An Inquiry

Approach" by Alfred E. Freidl. Investigative worksheets could be adapted for each lesson. Some of the main drawbacks for educators in implementing an effective science program is the amount of time and availability of materials to present lessons. An attempt to circumvent these drawbacks occurred in this project with positive results.

An extensive science background is not needed for effective elementary science inquiry. Science ideas can be effectively attained from student ideas, magazines, newspapers, supplementary books, parents, volunteers and etc. A majority of the lessons presented by this researcher did not have one single right answer to the specific problem. Several students did inquire about the right answer. A response to this query included "There is not enough evidence to find a specific answer." A follow-up to this query can have the student, teacher and/or parent discovering together to find the best answer by researching various sources such as the Internet or the library. An exact scientific answer for many scientific ideas may not be feasible for elementary students. Sometimes it is better to find the best solution that will have minimal impact. In some investigations- any solution given will have some sort of detrimental impact. One of the 'habits of mind' mentioned by the national benchmarks includes:

> By fostering student curiosity about scientific, mathematical and technological phenomena, teachers can reinforce the trait of curiosity generally and show that there are ways to go about finding answers to questions about how the world works. (AAAS, 1993)

An example of this was the exploration of the Snake River damming issue. The key is finding the one solution or solutions that minimizes negative impacts. The process to reach a solution is more important than the answer. If students and educators understand that there can be more than one answer to a problem and that the process of

inquiry is more important than product- then curiosity and desire to teach science can remain high. All in all, if science activities are easy to implement, allow for debriefing time, builds language arts skills, is relevant, and instigates curiosity in student and teacher, it is believed that more educators would place science higher in the elementary curriculum

Additional Implications

It is a reality that the educational environment is fluid and unpredictable. The nature of research is in itself is setting a path towards a goal or goals that may or may not be reached. Through the process of research, one gains invaluable data and insight. It is through these observations, insights and changes in course that discoveries are made. It is similar to Alexander Flemings' accidental discovery of penicillin which revolutionized the medical establishment. He probably did not realize the impact of his discovery until years later. Changes from discoveries can also occur, for example, in a young woman's observations of dolphins. Her work may someday help preserve the species and also the habitat the dolphins reside in. It can also be mechanic making an accidental discovery making an engine more efficient while working on a car. Those examples are similar to this research and others like it. Possible impacts of these research projects may or may not be realized until years later. Perhaps this research is one of many that will continue to build the foundation for changing the way science is taught in elementary schools.

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<u>Appendix A</u>

Investigative Activity Master Form

Title of investigation:

What I know....	My Predictions...

What I used...Materials	Vocabulary

What I did...Procedure:

What I saw....Observations

What I learned...Conclusions

Puyallup Model Investigative Worksheet Sample

Title: Chemical change. Lesson 9

What I know... A chemical change course a new turn to appear.

What I'd like to know... What is going to happen?

Materials

What I did... Procedure We put bakeing soda in a bottle. We put vinagar in a balloon. Then we put the vinager in the bottle.

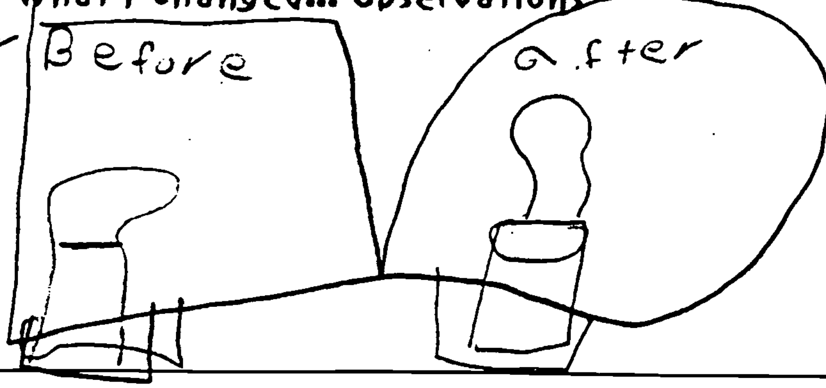
Vocabulary

vinegar

bakeing soda

carbon dioxide

What I changed... Observations



The mixture made CO_2 and the balloon inflated

What I learned... Conclusions I learned that when you mix vinigar and bakeind soda it makes a gas... carbon dioxide.

Appendix C

"Inquiry Exercise" Worksheet Explanation

Inquiry exercises has connections to Science EALR's 2-4; Communication EALR's 1-2 and Writing EALR's 1-2

This worksheet will help you in your inquiry of the discrepant event. This worksheet follows a method of inquiry. This is a method of inquiring a specific problem using a step by step approach to seek a solution. This worksheet will be used for all the inquiry exercises we will do.

1. What I'd like to know....Predictions. What I think is happening or going to happen in the demonstration. It is used to guide the direction of our inquiry.
2. What I used...Materials. Items that will be used in the experimental process.
3. Vocabulary. What are some words that are new.
4. What I saw...Procedures. How the inquiry will be carried out step by step.
5. What happened...Observations. Data and observations obtained from the observations
6. What I learned....Conclusions. The Conclusionary set can include questions posed by the student, teacher and the following questions:

    1. Was my prediction correct? What parts were correct.
    2. What did I learn?
    4. Were the results accurate or within reason?
    3. What can be done differently next time to achieve more accurate results?
    4. Why did the experiment/observation occur this way? Do I know why?

Appendix D

Inquiry Exercise Rubric

4	• Demonstrates thorough understanding by applying information learned in the investigation. • Forms logical inferences and predictions based on observations. • Student uses prior knowledge with an investigation by using relationships between one situation and another. • Student's work expresses and communicates clear intentions. • Writing legible with minimal grammar and/or spelling errors.
3	• Student responds using generalizations to investigations-limited outside knowledge. • Inferences and predictions are loosely connected to observations. • Student uses sometimes connects previous knowledge to the investigation. • Student seems to have an idea of what to express, but cannot always put experience into precise language. • Some spelling and grammar errors.
1	• Student knowledge limited to specific material presented-little or no use of outside knowledge. • Student rarely connects previous knowledge to an investigation. • Students work is disorganized and difficult to follow. • Makes little or no inferences and predictions. • Writing illegible and with numerous grammar and/or spelling errors.

Rubric includes elements of Science EALR's 2-4; Communication EALR's 1-2 and Writing EALR's 1-2

Appendix E

Proposed Research Flow:

I. Pre Student Survey
I
I
II. Teacher Modeling and explaining a method of scientific inquiry using the inquiry worksheet
I
I
III. Whole group inquiry exercises
I
I
IV. Rubric assessments (done throughout research)
I
I
V. Three possible outcomes
I
I

VI A. Gradual release to student lead inquiry I I	VI B. Gradual release to student lead inquiry I I	VII C. Gradual Release to student lead inquiry I I
VII A. Student initiated design and inquiry-innovative design. (High risk) I I I	VII B. Student stays with inquiry worksheet with little or no innovation.(Low Risk) I I I I	VII C. Student needs help to progress from one stage to another in inquiry. Or doesn't ask for help (No Risk) I I
VIII A. Post Student Survey- result is positive, enjoy science	VIII B. Post survey- neutral in science learning. Student doing what is required of him/her	VIII C. Post Survey- Science learning is negative, does not enjoy science or doesn't care

Appendix F

Actual Research Timeline:

Week #	Research Activities	Instructional Theme
1	Student questionnaire; explanation of investigative worksheet	Animal habitats- clues for animal presence
2	Continual explanation of investigative worksheet through modeled investigative activities	Animal habitats- deciphering animal presence through footprints. Impact on environments
3	Continual modeling of investigations Audio interviews of science surveys	Animal habitats- near the water- transition to land and water unit.
4	Guided inquiry through question prompts on investigative worksheet, audio interviews	Various lessons on the water cycle
5	Guided inquiry through question prompts on investigative worksheet, audio interviews	Activities relating to the damming of the Snake river
6	Guided inquiry through question prompts on investigative worksheet, audio interviews.	Continual inquiry surrounding dam issues. Investigation on impacts of dams on the economy and environment
7	Guided inquiry through question prompts on investigation worksheet	Investigations on watersheds and water flow.
8	Guided inquiry through question prompts on investigative worksheet- release of some responsibility to students, audio interviews.	Investigations on rivers and designing a safer dam
9 Science Week	Same as above and post survey. Science Week theme- human body and health issues.	5 day observation of what happens to bottles of milk which were given different treatments.

Appendix G

Pre Science Survey
Part I

Are you **Male** or **Female**- circle one

Please answer the following questions to the best of your ability. The first part will be short answer questions and the second part will involve you circling letters that best describe you. The letters stand for the following: SA = strongly agree, A = agree, D = disagree and SD = strongly disagree.

1. Circle your favorite subject:

ART PE SCIENCE READING WRITING

MATH SOCIAL STUDIES

2. What is science?

3. What do scientists do?

4. What do you think a scientist looks like? Write down a couple of words or draw a picture.

5. What do you do if you see a bright shell at the bottom of a puddle or tide pool?

Appendix G (cont.)

Pre Science Survey
Part II

Circle the letters that best describe you. SA = strongly agree, A = agree, D = disagree and SD = strongly disagree

You had a lot of science learning when you in 1st, 2nd or 3rd grades.	SA A D SD
Science is your favorite subject.	SA A D SD
You like to take things apart to see if they work.	SA A D SD
Science learning uses lots of reading and writing	SA A D SD
You can be a scientist.	SA A D SD
Reading and writing is required to learn science.	SA A D SD
I have enjoyed learning science this year.	SA A D SD
Science is important in our lives today.	SA A D SD
So far, I have learned a lot in science this year.	SA A D SD
You like to explore.	SA A D SD

Appendix H

Post Science Survey
Part I

Please answer the following questions to the best of your ability. The first page will be short answer questions and the second page will involve you circling letters that best describe you. Some of the questions are similar to the first survey I gave you.

1. Circle your favorite subject:

ART PE SCIENCE READING WRITING

MATH SOCIAL STUDIES

2. What do you learn when Mr. Liu helped Mrs. H teach science?- the main ideas (do not include materials learned when the Pacific Science Center was here or from parent helpers during science week)

3. What do scientists do?

4. What do you think a scientist looks like? Write down a couple of words or draw a picture.

5. What kinds of things did Mr. Liu do to help you in scientific investigations?

Appendix H (Cont)

Post Science Survey
Part II

Circle the letters that best describe you. SA = strongly agree, A = agree, D = disagree and SD = strongly disagree

Science is your favorite subject.	SA A D SD
You like to wonder how things work	SA A D SD
You like to read and write	SA A D SD
You can be a scientist.	SA A D SD
Reading and writing are required to learn science.	SA A D SD
So far, I have enjoyed learning science this year.	SA A D SD
Science is important in our lives today.	SA A D SD
So far, I have learned a lot in science this year.	SA A D SD
You like to explore.	SA A D SD
Scientific investigations have one right answer.	SA A D SD

Appendix I

Example of Student Work

The following progression of student work is from Sandy. Pre and post surveys are included. Inquiry worksheets from the Watersheds and Design a Safer Dam activities are not available from her. Blank copies are included. The circled numbers in the upper right hand corners of the worksheets represents the rubric ranking.

2/07/2000- Tracks I

2/10/2000- Tracks II

2/15/2000- Tracks III

2/17/2000- What Lives in This Habitat I and II

2/22/2000- Precious Water

2/23/2000- Water and Land Model

2/28-2/29/2000- To Dam or Not to Dam

3/09/-3/10/2000- Flash Flood Control

3/13-3/15/2000- Watersheds

3/20-3/21/2000- The River

3/22-3/24/2000- Design a Safer Dam

3/27-3/31/2000- Milk Observations

Title of Investigation: Tracks I
Name: Sandy Date: 2/7/2000

group

(3)

What I know....	My Predictions...
Some tracks look alike but they are not the same animal.	rabbit, because it has a long narrow foot print.

What I used...Materials	Vocabulary
sand, bowl, plaster of paris, H_2O, stamp, spray bottle.	cast fosel cast pad

What I did...Procedure:

First we put the sand in the bowl. Then spray the sand with H_2O 10 times. Then put the print on and put plaster of paris on it. Then let it dry and bush the sand off of it.

What I saw....Observations

Long foot print and four toes. And I think it is a Rabit

What I learned...Conclusions

It is a Rabit.

Title of Investigation: Tracks II
Name: Sandy Date: 2/10/2000

informative

(3)

What I know....	My Predictions... I think the animal is running because the back feet are in front of the front feet.

What I used...Materials	Vocabulary
brains pencils paper tracks	

What I did...Procedure:

Showed us a track
Asked what we saw
Predicted what the animal was doing

What I saw....Observations They are small tracks Hind feet are in front of the front ~~of the~~ f feet, they have furry feet there's 5 toes on the hind front = 4, pad claws precure on front and back of paw

What I learned...Conclusions

It is runnig because the front feet are in back of the hind feet.

Title of Investigation: Tracks III
Name: Sandy
Date: 2/15/2000

What I know....	My Predictions...
	(1) walking - start to run (2) run into each other and they get scared and scatter (3) one leaves (3)

What I used...Materials	Vocabulary
Sheets with tracks pencil	inference

What I did...Procedure:

What I saw....Observations I see two different kinds of tracks, TRACKS meet and scramble

I see two different kinds of tracks they meet and scramble then one pair leafes.

What I learned...Conclusions Two different animals are walking they meet and they fight. Then eather one got eaten or killed or it flew away.

Title of Investigation: What Lives in This Habitat I
Name: Sandy   Date: 2/17/2000

kids. (3)

What I know....about habitats	My Predictions...
I know different animals can live in the same habitat	I think ______ lives here because: Beaver - water wood - trees nice weather Limited humans - (low populat. wild animals

What I used...Materials	Vocabulary
pen or pencil Picture of environmenment investigation sheet	

What I saw....Observations

1) Large waterfall
2) a lot of water
3) some people
4) Lots of rocks
5) Lots of trees
6) Logs and sand

What I learned...Conclusions

Please answer the following: You can use the back of the paper

1. What did you learn today? I learned that I need more
2. What is some more evidence that will help you figure out better what lives here? food, scrapings, footprints, field guid,
3. Is the animal(s) your group chose commonly found in this environment? Why? Beaver because there is water,

Title of Investigation: What Lives in This Habitat II
Name: Sandy Date: 2/17/2000

2.5

What I know....about habitats	My Predictions...
• Chewings • pesticides • tracks • homes • droppings food water	I think Snowy owl lives here because: • trees • food • water • branches • snow

What I used...Materials	Vocabulary
pen or pencil picture of environment investigation	

What I saw....Observations

I saw snow covering the tree and branches with pinecones with a pond and tall grass bushes and rocks.

What I learned...Conclusions

Please answer the following: You can use the back of the paper

repitition of my lesson →
1. What did you learn today? We learned that we need more evidence to see whats really th
2. What is some more evidence that will help you figure out better what lives here? Scrapes, nests droppings. foot prints.
3. Is the animal(s) your group chose commonly found in this environment? Why? Yes. because the habitat for every thing the owl needs to survive.

we really didn't discuss what lives in each habitat.

Title of Investigation: Water and Land Model
Name: Sandy
Date: 2/23/2000

(2.5)

What I know.... about land and water	My Predictions... What will happen in this model?
• 3/4 water 1/4 Land • morewater than land	• I think the saranarap will fog up.

What I used...Materials	Vocabulary
• 3quart of the • sand • saranarap • water • tape • plug • ice • plastic ziplock Bag • clay • plastic bin	• surface runoff • Evaporation • Condensation • Transpiration • Water table • Precipitation

What I did...Procedure: (You can use the back if more space is needed)
I got my materials and put 3 cup of sand in and putthe plug in and put clay around it. Put the pad undernit. And watch what happends.

What I saw....Observations I saw fog starting to form on the saranarap were the ice is laying.

What I learned...Conclusions

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Please answer the following:

1. What did you learn? Nothing new
2. What did the ice do? It foged up the top
3. What can I do to get better results next time? I Do Not know
4. What difference does cold or hot water make? it fogs faster

Title of Investigation: Precious Water
Name: Sandy Date: 2/22/2000

(2.5)

What I know....about land and water	My Predictions...
More water than land 7 continents water cleans our bodies land gives us a place to live	.5 percent human usable water is important because.... we can not live without water. We need water to live.

What I used...Materials	Vocabulary

What I saw....Observations rivers, animals on land, dams, trees, field, humans, indians, houses, farms, clocks, paloushion, paper miles, fish, birds, matirials, people, irrigation,

What I learned...Conclusions

Please answer the following: You can use the back of the paper

1. How does pollution affect rivers? Pollution killes lots
2. How is what I learned today important to us? No knew water can come to the earth.

Title of investigation: Watersheds
Your Names:

What I know.... about watersheds	My Predictions... What will happen in this model? Mark where you think the water will go. Use the back or another sheet to draw your diagram. Also mark where you would build a house.

What did we use to build our watershed?	Vocabulary

How did you build your watershed? (You can use the back if more space is needed)

Observations Trace out the actual path of your water. Mark closed and open watersheds

Conclusions Please answer the following: 1. How is what I learned important? 2. What can I do next time to get better results?

Title of Investigation: Flash Flood Control
Name: Sandy   Date: 3/9-3/10/2000

(3)

What our company knows.... about dams and flooding	Company plans...
Dams provide electrisity, irriga	During heavy rains, the river experiences flash floods. The town council has asked your company to look into this problem. How will you solve this problem? Think about the environmental impacts too. A dam

Company Materials	Vocabulary
What will your company use to solve the flooding problem? Are company would first use a flood control dam.	Levee fish ladder flood control dam

What we did...Procedure: (You can use the back if more space is needed)

How did your design team solve the problem? List step by step First we will draw the plans. Then we will ask the council about our plan. Then if the council aproves our idea we will collect enough money

Blue prints

Use the record sheet 12-A to draw your blue prints (design)

What I learned...Conclusions

Please answer the following: You can use the back

1. How would you think your design will work?- give reasons Because it will keep flash floods from happening.
2. What are some other ways you can solve the problem? We could put a levee close to the town.
3. Is there anything else to add? More fish ladders

Title of investigation: Design a Safer Dam
Your Name:

What I know.... about Dams	The problem: The state asked your company to help make dams safer for fish. Draw out your plans, then write a short proposal.

What are you going to use to make changes to the dam	Vocabulary

How do you plan to make the dam safer? Write a short paragraph. Use the dam cross section to make a blue print of your proposal

Remember to be realistic with your plans- such as don't say "Blow up the dam"

Conclusions:

How will your changes affect how the dam works.

Title of Investigation: The River
Name: Sandy Date: 3/20-3/21/2000

(2)

What I know.... about rivers	My Predictions...
I know that when you do not have dams the river floods and it can cause a Lot of damidge. I also know	What will happen in our model? It will rot and finally evolve into water.
Describe your river section My river section has apice of an island on it.	Vocabulary Non-point Point Source

Methods- how did we build the "river" we atachcd them to each oter

Observations You think you don't give pollution but you do.

Conclusions

Please answer the following:

1. How is what I learned important? I Do Not know
2. What else can you add? OK

Title of Investigation: What's in the Jars
Name: Sandy Date: 3/27-3/31/2000

(3)

Predictions: What do you think will happen in each jar
1-yellow 4-sour-
2-brown 5-freeze
3-plain

Materials:
Jars milk soil
viniga refrigarater

Observations: Describe what you saw everyday in the jars

	Day 1	Day 2	Day 3	Day 4	Day 5
Jar #1 Control- room temp. lid on	yellow	yellow	smells sour	Yucky	I see yellow liquid on bottem and goowsoft stuf on top.
Jar #2 Some soil added lid on	brown	brown	smell like dirt	YUCKY	On top I see hard chunky milk with soil mixed on bottem I see yellow liquid on top.
Jar #3 Vinegar added- lid on	plain	chunky	smells nasty	yucky	I see slimy white milk
Jar #4 Nothing added lid off	Sour	Sour	smells moldy	yucky	I see yellowish witeish milk
Jar #5 Nothing added- cold- lid on	cold	cold	smells like baby potter	yucky	It is the same as milk in a regalar jug or carto

Results:

Briefly summarize what you saw and smelled in each jar on day five;

1. Yellow Liquid on ~~bottom~~ bottom and goowi soft stuf on top.
2. Hard, chunky milk and soil mixed on bottom and yellow Liquid on top.
3. I see slimy white milk
4. I see yellowish witeish milk
5. It is the same as milk in a regular jug or carton

Conclusions:

1. Which parts of your predictions were correct? Which parts were incorrect? (example: I was right when I predicted the jar with soil added would be really gross and I was wrong when I said the jar with vinegar would not smell at the end of five days)

1. I said it would be yellow - I was correct
2. I said it would be brown - I was correct
3. I said it would stay the same - I was correct
4. I said it would get sour - I was Incorrect
5. I said it would freeze - I was Incorrect

2. What do you think happened in the jars? I think I got bactirea and it got warm.

3. What do these findings mean to you? These finding teach me that if you leave milk out bactiria will grow

LEARNING SCIENCE THROUGH READING: FIFTH-GRADE STUDENTS' CONCEPTUALTION OF OBSERVATION AND INFERENCE

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One of the Ohio Sixth-Grade Science Proficiency Learning Outcomes is to make inferences from observations of phenomena and/or events. Related information about Ohio's Sixth-Grade Science Proficiency Test content states, "By the sixth grade, students should clearly understand the difference between an inference and an observation" (Ohio Department of Education, 1994, p. 59). Benchmarks for Scientific Literacy states, "By the end of the 5th grade, students should be able to keep a notebook that describes observations made, carefully distinguished actual observations from ideas and speculations about what was observed, and is understandable weeks or months later" (American Association for the Advancement of Science, 1993, p. 293). However the National Science Education Standards encourages, "Changing emphases to promote inquiry: less emphasis on individual process skills such as observation or inference; more emphasis on using multiple process skills — manipulation, cognitive, procedural" (National Research Council, 1996, p.113). Although arguments have been made that students must know the individual science process skills before entering into the "multiple process skills" or integrated process skills (Ostlund, 1992; Ostlund & Mercier, 1997-8; Rezba, Sprague, Fiel, Funk, Okey, & Jaus, 1995), the degree to which students should know the process skills of observation and inference needs to be addressed.

The understanding of observation and inference can be one of degree or one of kind. "Difference of degree makes differences between the kinds of things which differ in some further way; difference of kind make difference between different kinds of things" (Lipman, Sharp, & Oscanyan, 1984, p. 173). Observation and inference may be distinctly different, discontinuous concepts or interrelated, continuous concepts. Middle school students sense-making an

observation and inference can be either one of difference of kind or difference of degree. The purpose of this study is to examine how middle school students make sense of the concepts of observation and inference.

Lee (1991) defined sense-making as the process by which an individual attaches meaning or interpretation, examines the meaning or interpretation and considers the influence of the meanings and interpretations. Ebert and Ebert (1993) created a model in which sense-making of teaching must include what teachers do; how teachers do what they do; and why teachers do the "whats" and the "hows." For this study, sense-making is what students know and are able to do, how students learn, and why students learn. More specifically, what do the concepts of observation and inference mean? How do students construct the meaning of observation and inference? Finally, what are students able to do with their definitions?

Scientific Observation and Inference

Although many view the difference between observation and inference as a difference in kind, some the difference is one of degree. Some argue the natural inclination of students is towards making inferences. Tippins and Pate (1992) state, "young children typically make observations before they make inferences" (p. 12). By definition inferences are based upon observation. The proponents for difference in kind have students state observations or write observations and then draw inferences. On the other hand, Lederman and Abd-El-Khalick (1998) have students list inferences and then work backwards to the observations.

Differences of Kind

Difference of kind is denoted by the separation of observation as a process skill from inference as a different process skill. Ostlund and Mercier (1997-98) used the direct versus not direct use of senses argument. Matthews (1992) also distinguishes between observation and inference. Inferences are hypotheses as "invalid hypotheses can be identified and discorded" (p. 32-33). In other words inferences can be evaluated, but observations are "real." Scarnati (1993)

stated "students should soon recognize that an inference is not a direct observation; rather it is only one of many interpretations of the situation based upon observation" (p. 24). His test is the "How do you know?" question. True observations lead to "the senses" as a source of proof; whereas inferences demand testing.

Akerson, Abd-El-Khalich and Lederman (2000) used "two other activities ('Tricky Tracks!' and 'The Hole Picture!') [to address] differences between observations and inferences and to assess the influence on preservice elementary teachers' concepts of the nature of science" (p.300). The Tricky Tracks! activity was "designed to help students make the crucial distinction between observation and inference and appreciate the tentativeness of scientific knowledge and the role of creativity in science" (Lederman & Abd-El-Khalich, 1998, p. 85) and The Hole Picture! was "intended to reinforce students' understanding of observation and inference in science" (p. 91). The participants in Akerson, Abd-El-Khalich and Lederman's (2000) study increased their ability to distinguish between observation and inference and hence "made relatively more gains in their understandings of the tentative, creative, and imaginative nature of science" (p. 312).

Ridgeway and Padilla (1998) described the observation and inference difference with William S. Gray's content area reading model: "reading the lines [literal], reading between the lines [inferential] and reading beyond the lines [application]" (p. 19). Their guided thinking model consist of three levels: "what is observed (literal), relationship between and among observations (inferential). and conclusions that go beyond the observations (application)" (p. 19). However Ridgeway and Padilla do not teach students to make distinctions between observations and inferences. Students recognize the difference because the "guided thinking" guides contain a list of observations (Part One) and a list of inferences (Part Two). For example, "we give the guide [list of observations] to students after they have made their own observations so that it will not schew their results according to what they think is expected of them." (p. 20).

Schrader (1984) stated "scientific modeling techniques depend quite heavily on being able to distinguish observations from inferences" and he gives to his students "definitions and common examples of observations and inferences" (p. 1002). He furthermore refined the distinction between the two by noting that inference is a higher order thinking activity. "My objective at this point is to encourage students to be analytical and creative in making their inference.... It may be correctly argued that we can do analysis, synthesis and evaluation in connection with almost any observation" (p.1002). Inferring requires evaluation and judgment based on past experience (Ostlund, 1992; Ostlund & Mercier, 1997-8).

Difference in Degree

Driver, Leach, Millar, and Scott (1996) argue that the focus on process skills (in general and specific) do not lead to understanding the nature of science and they argue that the process skills, once learned, are not transferable across context. When students engage in scientific inquiry, they do not discriminate between observation and inference, however, students usually make different degrees of inferences in order to form hypotheses (Millar & Driver, 1987). In an exploratory study, Broadway and Mason (2001) concluded middle school students will include in their explorations of objects and substances those properties which they perceive with their senses, and more importantly, those properties which they perceive based upon their past experience.

Observation and Inference in Reading

Readers observe text; readers inference meaning. "In reading, comprehension processes are generally assumed to combine information from two sources: explicit statements from the text being read and general knowledge already known to the reader" (McKeon & Ratcliff, 1992, p. 440). Writings are ambiguous. Therefore, writers expect the readers to bring their prior knowledge to reading (Corbett and Dosher, 1978). Inference involves both reading between the line, (Anderson, Reynolds, Schallert, & Goetz, 1977) and reading beyond the line (Honsen,

1981). Drawing inferences requires activation of the reader's prior knowledge (Anderson, et al, 1977). Therefore, for reading, the relationship between observation and inference is clear. Observations include the written text and inferences are the meanings attached to the text by the reader

Research Question

Although the practices of observation and inference are conceptually alike in science and reading, this study tries to teach a scientific skill and a reading skill rather than teaching science through reading. In other words, this study avoids Dickinson and Young's (1998) concern that "students...may view science as a body of knowledge about which they must read and write and will not experience inquiry activities to help them learn science processes" (p. 335). Upon decontextualizing or abstracting the concept of observation and inference from the concrete context of story and activity (Wertsch, 1985), the research question explores the conceptual understanding of observation and inference formed by fifth grade students.

Methods

Participants and Setting

For this study, the second author taught the lesson to 18 fifth grade students. Students in the class were assigned pseudonyms. These students attended a school in a city district within a rural county in the north central region of a Midwestern state. Some of the students were assigned a resource teacher who interacted with the students and participated in the activities with the students.

The classroom was one of three sections of a long room which housed "The Learning Village." The Learning Village was the name given to three classrooms which formed a larger community of learners: a grade one-two class; a grade three-four class; and a grade five-six class. Most of the time, the room was open so that students could move between the other classrooms in the village. The students often interacted with the other multiage classes as well as worked

separately which was the case during this lesson.

The Activities

Towards a Concept of Observation and Inference

*Seven Blind Mice (*Engagement*)*

The Text. *Seven Blind Mice* (Young, 1993) is a retelling of the classical Indian tale of blind men describing an elephant. The descriptions and sense-making of the mice was organized according to what was stated and what elephant part inspired that statement (See Figure 1).

Figure 1

List of Mice's Sense-making in *Seven Blind Mice*

Mice		
Red	leg	pillar
Green	trunk	snake
Yellow	tusk	spear
Purple	head	cliff
Orange	ear	an
Blue	tail	rope
White	...she ran up one side, and she ran down the other. She ran across the top and from end to end.	an Elephant

One column contained "what the mice said" and the other column contained "what lead to that statement." "What the mice said" corresponded to the inferences the mice made, "What lead to that statement" represented the parts of the elephant the mice observed.

The Task. The second author read *Seven Blind Mice* (Young, 1993) two times. The first reading was without directions. For the second reading the students were directed to look for

things the mice said and what lead to that statement. Students gave examples before the second reading. After the second reading, one copy of the text was given to a group of four students. Each student was given a T-chart (See Figure 2). The students completed the T-chart.

Figure 2

T-chart to Record Mice's Sense-making in *Seven Blind Mice*

mice		
red	leg	pillar

After the students completed the T-chart. They were instructed to describe the things on the right and on the left side of the T-chart. However, most students responded when "they had already described the things." Then, the students were presented with a similar example. The right column was labeled "weather," and "clothing" was the label for the left column. Again, the students were asked to describe the words in the *Seven Blind Mice* T-chart.

*Flossie and the Fox (*Exploration*)*

The Text. Flossie and the Fox (McKissack, 1986) is about an African-American girl who takes some eggs through the woods to the McCutchin Place where the hen house was constantly raided by a fox. The focus of the story is that Fox must prove that he is a fox: Fox offers proof to Flossie and she responds to Fox's words (See Figure 3).

Figure 3

List of Fox Statements and Flossie Statements

FOX	FLOSSIE
1. "I have thick, luxurious fur."	1. "...feels like rabbit fur to me..."
2. "I have a long pointed nose."	2. "...rats got long pointed noses..."
3. Cat (voice of the fox) "Sharp claws and yellow eyes."	3. "...both y'all got sharp claws and yellow eyes..."
4. "I have a bushy tail."	4. "...you got a bush tail, so do squirrels..."
5. "I have sharp teeth and can run exceedingly fast."	5. "...hounds behind you. He's got sharp teeth and can run fast too."

In one case another character, Miz Cat, speaks for Fox .

As illustrated in Figure 3, *Flossie and the Fox* yields data for readers to discriminate as to which are observations and which are inferences. The Fox's statements are properties of an object perceived through the use of the senses. On the other hand, Flossie's statements are inferences which are explanations or interpretations of an observation.

The Task. The activity began with the reading of *Flossie and the Fox* (McKissack, 1986). After the reading, the students discussed the plot.

> "Are you saying I must offer proof that I am a fox before you will be frightened of me?
>
> "That's just what I'm saying. (p.14).

For the classification task, each student was instructed to construct a table similar to Figure 3. After listing the "proof" Fox offered Flossie and Flossie's response, the students described what kinds of statements were on each side of the chart.

<u>Inferring</u>

*Yo! Yes! (*Exploration*)*

The Text. Yo! Yes! (Raschka, 1993) is a conversation between two boys. On one page is a White boy and on the next page is an African American boy. Raschka (1993) uses short

sentence of no more than three words, but most often one word to tell a story. As *Yo! Yes!* is a Caldecott Award book, the illustrations speak "a thousand words." The literal text provides observations from which the students of the study made inferences. According to McIntosh (1985), *Yo! Yes!* (Raschka, 1993) exemplifies a synthesis:

> If writers did not assume that their readers approached written materials with some knowledge of the world and with the ability to apply that knowledge in understanding the text, then writers would have to be so verbose that readers would become bored quickly....Until (and unless) readers draw inferences, a text is nothing more than a collection of separate words and sentences (p. 755).

The Task. Two students read the story to the class. One student reads the White boy's words and the other student reads the African American boy's words. After the reading of the book, the students were instructed to rewrite the story using four or more words to represent the conversations between the two boys in pairs. Unlike the *Seven Blind Mice* and *Flossie and the Fox* tasks, the students actively inferred rather than described the inferring behavior of the characters.

After the students completed the task, the whole class talked about how they created their conversation. Specifically, they were asked "What [in the text] did they use to tell them how to write their conversation."

Explanation

After the completion of the three tasks above, the class discussed the similarities and differences in the exercises. The second author connected the three tasks by introducing the terms observation and inference. Each of these terms were then applied to each of the tasks.

*Footprints (*Elaboration and Evaluation*)*

The class was shown position 1 of the Footprint (Tricky Tracks!) activity (Lederman & Abd-El-Khalich, 1998; Rezba, et al 1995; Scarnati, 1993). Each student in the class brainstormed

one observation: "The two animals were walking towards the same place" and then one inference "They both were going to the same place." Then, the second author wrote "Footprints gets further apart" from the Record Sheet (Rezba, et al 1995, p.75). One student inferred, "It could have jumped." Another student inferred, "It could have started running." The students were then handed the Record Sheet and instructed to write one observation/inference pair for each position.

Data

Each task generated written data. *Seven Blind Mice* generated a T-chart with descriptions of the word in each column of the T-chart. *Flossie and the Fox*, likewise, created a T-chart with summaries for each column in the T-chart. *Yo! Yes!* generated a conversation between characters. Lastly, the footprints task generated three observation/inference pairs. The second author took notes of her instructions and the whole class conversations after each session.

Analysis

The descriptions were read and reread in order to uncover themes, patterns and topics in the students' writings. As themes, patterns and topics unfolded, classification schemes were designated. The writings within a task were sorted based on the classification scheme.

However, some *a prior* classifications were established. The *Seven Blind Mice* and *Flossie and the Fox* tasks were designed to illicit definitions of observation and inference. Vygotsky (1987/1962) and Whitin and Whitin (1997) suggest student-generated classification labels are important to determine students' sense-making of tasks. Hence, the writings were specifically analyzed in order to unfold definitions.

The *Yo! Yes!* task was designed, *a priori*, to have students actively involved in inferring. The students were actively involved in a science process skill and a reading skill. Therefore the *Yo! Yes!* writings were analyzed in terms of the students' ability to infer.

A prior, the Footprint task was designed to evaluate the application of the

observation/inference concept and sense-making, and to evaluate students' ability to observe and infer. Thus, observation/inference pairs were analyzed pairwise.

Findings

Identifying Observations and Inferences

Seven Blind Mice

All students were able to complete the *Seven Blind Mice* task. When instructed to write headings for the columns, the majority of students could not classify the different groups of words, except for four students. The majority of students wrote variations of "I don't know" or "I don't understand." However, before Preston wrote "I don't understand," he crossed out"They [pillars, snakes, etc.] are descriptions of the others [legs, trunk, etc.]"

Two students made clear statements: "I wrote about what the mice thought about when he said 'It's a pillar,'" (Ralph) and "The pillar, snake, cliff, fan, rope have describing words, those describing words are like characteristics" (Adrienne). Roberta wrote a description for each column. One column was termed "Those words are all nouns." The other column was labeled "These statements are all describing statements for body parts." The majority of the students did not communicate and understand, but those students that labeled the columns denoted describing.

Flossie and the Fox

The responses to *Flossie and and the Fox* can be divided into three groups. One group did not understand the task. However, like the other groups, this group could complete the task as illustrated in Figure 2.

The second group reiterated the plot of the text. For example, Bob called the Fox column "All the statements Fox makes trying to prove he's a fox,"and the Flossie column "All the statements Flossie made just to throw the fox off track so she can get the eggs safely to Miz Viola." For Mark, Fox statements were "The fox was describing to her that he was a fox" and

Flossie statements were "Flossie knew that he was a fox all along." Within the group all students classified Fox statements as descriptions. Flossie statements were plot devises or a literal summary of the plot.

The third group also classified Fox statements as descriptions, however, the Flossie statement descriptions contained elements of inferences. For these students Flossie related characteristics of a fox to other animals. Roberta wrote, "These are a group of statements that show different animals that have things in common with a fox." Carol stated, "She said, 'No!' because other animals had the same thing." The connotation in the Flossie statements was Flossie had prior knowledge of some animals, although not information concerning foxes (McKissack, 1986. p. 9), to determine if the fox was a fox. In other words, this third group of students recognized the role of past experience in Flossie's statements.

Inferring

Yo!Yes!

All students were able to draw inferences. Text clues and illustrations were used by the students to create the conversations. Text clues included rhythm of the text and punctuation. Facial expressions and body motions were clues in the illustrations. The students communicated that they were using their prior knowledge in order to make inferences from the text.

Assessing Observation and Inference

Footprints

The students either explicitly stated or implied the same narrative for the Footprints. Position 1 indicated a large animal and a small animal coming closer together. Position 2 indicated an interaction between two animals. Lastly the large animal departed leaving prints in Position 3.

Observations

Most of the students' observation statements were inferences. Two students placed observations in the observation column. Similar to the Self-Check's example "The prints become

all mixed up" (Rezba et al, 1995, p. 76), Samuel stated, "Footprints collide." On the other hand, Karen made the observation, "Footprints are in a circle" which has no parallel in the Self-Check list.

The other observation statements were either inferential observation statements or descriptive observation statements. An inferential observation statement is descriptive, however it communicates the context. For example for Position 1, Mike wrote, "Two animals where walking and their paths met." Although not explicitly indicating the footprints, the statement connotes two sets of prints (two animals) and a decreased distance between the footprints from left to right (their paths met). Secondly, if Mike's observation statements were given out of context, the reader would envision position 1 as the prompt.

Mike's wrote for position 3: "The carnivorous one was a bear and the other a duck." This is an example of a descriptive observation statement. His statement is not connoted by the text. Position 3 does not yield data that can determine if the maker of the footprints was a carnivore.

As stated above, the fifth grades wrote a diverse array of observation statements, In order to help the reader understand the diversity of statements placed in the observation column, the authors invite the reader to exam the observation statements that follow in the analysis of inference statements. The reader will note that the observation statements are either inferential observation statements or descriptive observation statements. A good measure for distinguishing the types of observation statements would be to see what one drew if they knew that the prompt contains only footprints. Inferential observation statements would resemble the Footprint worksheet and descriptive observation statements would not.

Inference statements

Inference statements by definition go beyond the text and depend on evidence. Therefore, there is no classification system for the inference statements. However some statements may be

more plausible than others, but this criteria does not support the research question. However, inference statements may be examined in connection to the student's observation statements. Analysis of the pairs lead to the following relationships: narrative non-relationships, explanatory relationships, evidential relationships, and casual relationships.

Narrative non-relationships. Two fifth grade students wrote one statement for both the observation and the inference position of the worksheet. These examples tell a story without distinguishing between observations and inference. For example Randolph wrote:

Two animals are walking towards each other. (Position 1)

The two animals got in a fight. (Position 2)

The bigger animal left the little one to die. (Position 2)

However, some students who did distinguish between observations and inferences wrote narrative solely. Mike wrote a narrative (see Figure 4),

Figure 4

Mike's Response to Position 2 of Footprints

	Observation	Inference
Position 1	Two animals where walking and their paths met.	They were both following each other.
Position 2	One started chasing the other.	One was carnivorous.
Position 3	The carnivorous one was a bear and the other a duck.	The duck was eaten.

In this example, the observation or inference is built upon the preceding observation *or* inference so that a story unfolds.

Evidential relationships. In an evidential relationship, the student gives a characteristic from the Footprints as an inference. Therefore,these students make observations. As an example,

Martha wrote inferences for position 2 which serve as evidence for her observation statements (See Figure 5),

Figure 5

<u>Martha's Response to Position 2 of Footprints</u>

	Observation	Inference
Position 2	They ran into each other	The foorsteps crisscrossed
	They ran around in circles	The foorprints went around in circles

Edith did likewise for position 3 (See Figure 6)

Figure 6

<u>Edith's Response to Position 3 of Footprints</u>

	Observation	Inference
Position 3	The bigger one killed the little one	becasue only one [print] leaves the circle

The statements in the inference column are quality observation statements. Most evidential relationships contain observations in the inference column. Students who wrote evidential relationships were able to make observations, however, they are not able to identify the statements as such, nor to communicate their understanding in the manner expected of them.

Causal relationships. Unlike evidential relationships, a casual relationship has inferences in both the observation column and the inference column. Whereas evidential relationships have observational inference statements, causal relations contain inferential inference statements. Inferential statements are contextually described as they connote "Footprints." For example Samuel wrote a causal relationship for position 2 (See Figure 7).

Figure 7

Samuel's Response to Position 2 of Footprints

	Observation	Inference
Position 2	The footprints collide	Because there were 2 animals

In this example, the statement in the inference column is an inference and the statement in the observation column is an observation upon which an inference was constructed.

Explanatory relationships. Explanatory relationships contain inferences which are descriptive. These descriptive inferences do not connote the Footprint context. For example Linda wrote on position 2 (See Figure 8).

Figure 8

Linda's Response to Position 2 of Footprints

	Observation	Inference
Position 2	The animals met and fought	They did not want the other there

The inference statement by itself does not correspond to Footprints; however, it does attach meaning to the inferential observation statement. Another example, by Wanda, is in Figure 9. .

Figure 9

Wanda's Response to Position 2 of Footprints

	Observation	Inference
Position 2	The animals are fighting.	The bigger animal could {have] been hunting it's prey

In both examples, the students placed inferences in both the observation column and the inference column. There is no attempt in explanatory relationships to make observations. However, explanatory relationships are different from non-relationships because there is a

plausible connection between the statements.

Conclusion

- All fifth grade students were able to make inferences and a few fifth grade students made observations. However, some of the observation statements were called inferences.
- Students could not distinguish between observations and inferences
- The fifth grade students were not able to recognize or label examples of observations and inferences.

Discussion

For these fifth grade students, both observations and inferences are descriptions. Hence, observations and inferences are a different degree of descriptions.

These fifth grade students brought a language arts knowledge and framework into a science learning setting which used literature. When students are asked to give an observation, to link what they observe with their prior knowledge, or to give an explanation or interpretation of what they sense (Rezba, et. al., 1995) in a science setting, students will use a language arts understanding of description. Description in the Language Arts aims towards description, rich in detail and context. Hence, these fifth grade students viewed the Footprint task as a language arts task, not a science process task. The majority of the descriptions told a story. The extreme descriptions were the narrative examples. If these participants understand description as a language arts skill, do these fifth grade students see observing as science storytelling?

Observation and inference must exist in a larger context if they are to become part of science storytelling . This is the view of the National Science Education Standards. Observation and inference, as part of integrated process skills, may be more meaningful to these middle school students. For these students, the distinction between observation and inference is less important than the nature of science model of understanding science. Rather than ask the "logical explanation" characteristic of inference (Rezba, et al., 1995, p.70), teachers should ask nature of

science questions such as What is the evidence? How do we know? Why do we believe? How do we find out?

Thoughts on teaching observation

Teaching Difference of kind

In order to teach observations, students need to perform pure observations. Instruments are tools used to observe. By definition, instruments are an extension of the human senses and thus, record what the senses sense. Therefore, when teaching observations, it is important to emphsize that observations are what instruments communicate. Maybe the word "to measure" should be replaced with "to observe." Maybe observation should be defined as what instruments measure. Thus in science teaching, the term *observation* should be connected with measurement rather than inference and introduced after a firm understanding of instruments and measurement has been established.

If observation and inference must be taught as a difference of kind, then observations, especially quantitative observations, must be taught first. Once students have mastered quantitative observations, then instruction should work backwards to construct qualitative observations. Otherwise, as in the case of these fifth grade students, observations will be understood as description and used in the vernacular sense of inference.

A new point of view about observation and inference in reading

The connection between observation and inference as a reading skill versus a science process skill may be difficult to understand because the reading equivalent of observation is unlike the science process skill of observation. The text serves as the observation in reading. The science process skill of observation represents cognition of the (con)text. In other words, in reading, readers go directly from the object to the inference. The reader does not make an observation. The reader is given an observation. In science, the scientist makes an observation about the object and makes an inference.

Furthermore, observation in reading is synonymous with inference. When a reader is asked to make observations about the text, the reader is being asked to make inferences. If the text is a record of authors' observations, then the reader can not make observations about the text. When looking at *Seven Blind Mice*, *Flossie and the Fox*, and *Yo! Yes!*, the reader needs to understand that these stories reflect how the authors decided to communicate their observations. The reader must infer the authors' meaning as well as construct their own meaning. This connection between text, observation and inference was not clear to the fifth grade students in this study. Hence, the students were not able to transfer meaning of observation and inferences into two different content areas: science and reading. The use of any given mental operation is context-dependent (von Glasersfeld, 1995). From a science process skill perspective, in reading, both inferring the author's meaning and constructing personal meaning are called inference.

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DOES BEING WRONG MAKE KETTLEWELL WRONG FOR SCIENCE TEACHING?

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Biology teachers routinely introduce the concept of natural selection with reference to a fairly standard account of the phenomenon of industrial melanism based on the work of H.B.D. Kettlewell in the early 1950s (Kettlewell 1955, 1956, 1958). As some of you may know, I have been doing research for the past few years on a book devoted to his investigations. One major theme of the book is exploring the extent to which the actual historical details of Kettlewell's work constrain how it is depicted in science textbooks. Today I will briefly contrast what has come to be known as the classic textbook account of the phenomenon of industrial melanism with what is actually known about the phenomenon. While some scientists, such as Jerry Coyne (1998), contend that these differences undercut the value of using the phenomenon of industrial melanism as an example of natural selection, I will argue instead that these discrepancies actually augment the value of discussing the phenomenon of industrial melanism and Kettlewell's work in particular, to teach evolutionary biology.

I'll begin first by reviewing the classic textbook account: what the phenomenon of industrial melanism is, how scientists explain the phenomenon, and what evidence they attribute largely to Kettlewell in behalf of this explanation. I'll then identify several of the many discrepancies between this textbook account and what is actually known about the phenomenon and Kettlewell's work on it. My analysis will then turn to an examination of the import of these problems, and review some of the advantages of the classic, albeit

false, account. I will argue that the discrepancies between the two accounts actually underscore the potential value of using Kettlewell's work, and history of science more generally, for the teaching of science.

The Classic Textbook Account

Let me give you an example of what I take to be a fairly standard view on Kettlewell's work on the peppered moth, offered as an illustration of natural selection. This exerpt on industrial melanism taken from an introductory biology textbook by Mader (1988), which I've chosen primarily for its brevity:

> Before the industrial revolution in England, collectors of a moth called the peppered moth noted that most moths were light colored, although occasionally a dark-colored moth was captured. Several decades after the industrial revolution, however, black moths made up 99 percent of the moth population in polluted areas. An explanation for this rapid change can be found in natural selection. The color of the moths, dark or light, is caused by their genetic makeup; black is a mutation that occurs with some regularity. Moths rest on the trunks of trees during the day; if they are seen there by predatory birds, they are eaten. As long as the trees in the environment are light in color, the light-colored moths live to reproduce. But once the trees turn black due to industrial pollutants, natural selection enables the dark moths to avoid being eaten and to survive and reproduce; therefore the black phenotype becomes the more frequent one in the population. This explanation has been supported by experiments in which both dark- and light-colored moths were released into industrial and nonindustrial areas. In the industrial areas, the light moths suffered more attrition; in the nonindustrial areas, the dark moths did not survive. This shows that the phenotype most adapted to the environment is the one preserved in nature. Industrial melanism has also been noted in the United States; around major cities the insects have taken on a darker color than in the unpolluted countryside. (p. 520).

Here are photographs of the two forms of the peppered moth in the polluted and unpolluted settings (Figures 1 and 2) often used to illustrate such accounts.

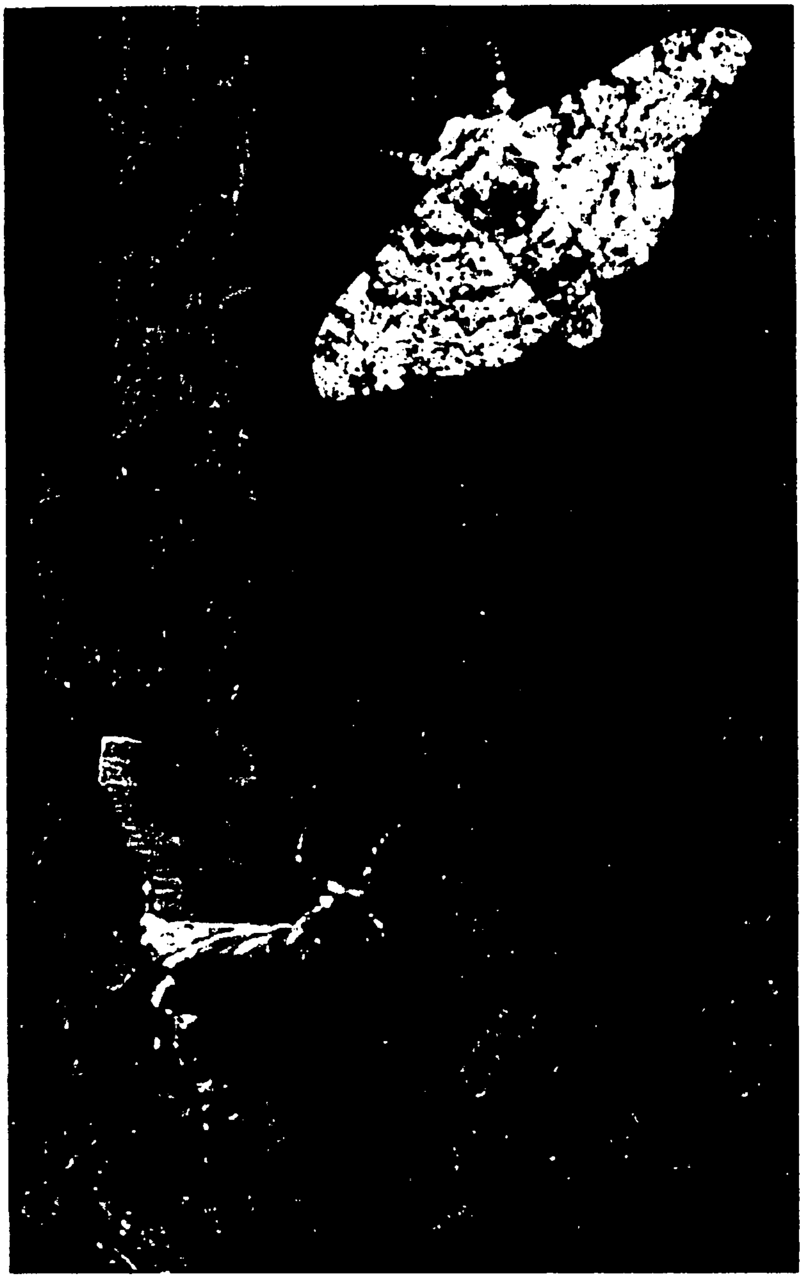

Figure 1. Plate of *Biston betularia* L. f. *typica* and its melanic f. *carbonaria* (__1) on polluted Oak trunk (Birmingham). (Reproduced from Kettlewell 1973 Plate 8.2 by permission of Oxford University Press.)

Figure 2. Plate of *Biston betularia* L. f. *typica* and its melanic f. *carbonaria* (__1) on lichened Oak trunk (Dorset). (Reproduced from Kettlewell 1973 Plate 8.1 by permission of Oxford University Press.)

We can analyze this example of a textbook account of the phenomenon of industrial melanism into a series of claims about the phenomenon, our explanation of it, and the evidence Kettlewell provided by means of his investigations in favor of it:

Claims Made By The Classic Account

1. The peppered moth, *Biston betularia*, had two forms, a common pale form (*typical*) and a rare dark form (*carbonaria*).

2. The peppered moth spends most of the day motionless on trees in plain sight.

3. Birds are visual predators on the moth.

4. The industrial revolution led to the first large scale pollution, killing off the lichen cover and visibly darkening trees and other resting sites downwind of manufacturing centers.

5. Naturalists noticed that, coincident with these changes, the heretofore rare dark form of the moth (*carbonaria*) was becoming more common in areas downwind of manufacturing centers.

6. It is obvious that the phenomenon can and should be explained with reference to natural selection. The dark form of the moth was becoming more common in areas downwind of industrial sites because its dark color, which earlier made it very conspicuous to birds, now camouflages it against visual predators.

7. There is consensus that Kettlewell established this by means of a series of elegant experiments in polluted and unpolluted settings. The experiments consisted of marking moths of both types, releasing them into the woods in both settings and then recapturing as many of the moths as possible. In polluted settings, Kettlewell was able to recapture more of the dark form; in unpolluted settings, he recaptured more of the pale form.

The phenomenon of industrial melanism is encapsulated in the first five claims, the explanation in claim six, and the evidence in claim seven.

Problems With The Classic Account

In his comprehensive review of the scientific literature on melanism, Michael Majerus (1998) recounts several deficiencies that attend to this standard account. While some of the simplifications textbooks adopt may reflect the removal of superfluous detail, for instance the fact that the pale speckled appearance of the typical form of the peppered moth actually represents a complex pattern, others are more serious. Let me just call your attention to a couple of these:

Regarding the first, the peppered moth actually has two dark or melanic forms, not just one. The second form, known as *insularia*, is now known to represent a complex of forms that range from the pale appearance of *typical* to the soot black appearance of *carbonaria*.

Regarding the second, other than a couple of anecdotal accounts, it is not known whether the moth actually rests on the surfaces of trees in plain view. There is some evidence to suggest that the moths actually spend the day on the undersides of the boughs of trees (e.g. Mikkola 1984). If so, they would be spending their time in the shade, which of course would obscure any differences due to color.

Regarding the third, a number of investigators dispute that birds constitute a significant predator on the moths - several have suggested that the predation levels Kettlewell observed during his experiments were an artifact of the high densities of moths he used (e.g. Clarke and Sheppard 1966). In other words, it is possible that birds that ordinarily never eat the moths at all could become conditioned to eat them when the moths are present at high enough densities.

Regarding the fourth, the account does not mention that melanic forms were known to be present in many moth species prior to the industrial revolution, and further falsely suggests that melanism has evolved in all species by the same mechanism.

Regarding the fifth, it has long been known that frequencies of the dark form of the peppered moth, *carbonaria*, are high not only in industrial areas, but also rural areas as well.

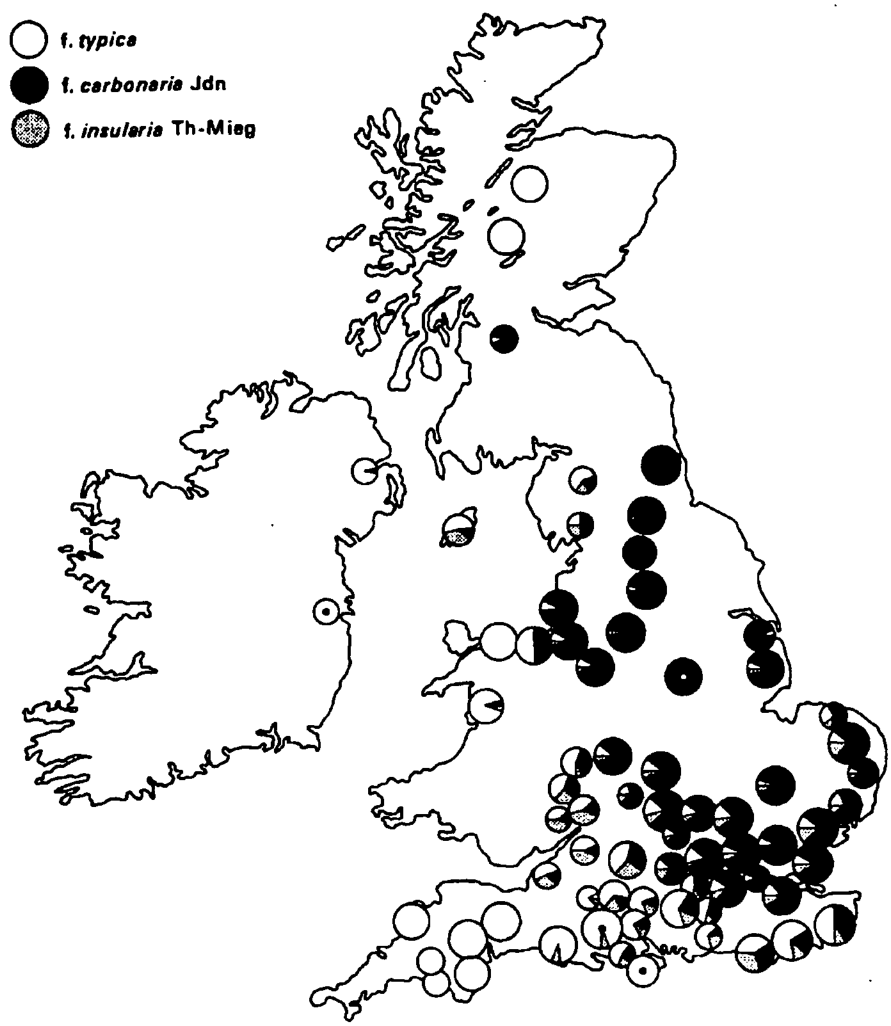

Figure 3. A frequency map of *Biston betularia* and its two melanics, f. *carbonaria* and f. *insularia* comprising more than 30, 000 records from 83 centres in Britain. (Reproduced from Kettlewell 1973 Figure 9.1 by permission of Oxford University Press.)

Above is a map of frequencies taken from Kettlewell's 1958 paper often included in the textbook accounts that reveals this (Figure 3). Of course, the reader is never informed of this anomaly.

Regarding the sixth, scientists debated a number of different theories to account for the rapid rise in the frequencies of the dark form of the moth downwind of industrial sites; several of the early theories posited it was a consequence of Lamarckian inheritance or mutagenic properties of pollutants contained in the soot. And while it is true that Kettlewell worked under an explanation of this phenomenon in terms of natural selection, the actual model that he tested, developed by E.B. Ford, invoked two selective forces, of which the advantage of color in protecting dark moths in polluted environments, technically referred to as "crypsis", was initially proposed as the less important (Ford 1940). Ford claimed that the rapid rise in the frequency of the melanic forms was due to a pleiotropic effect of the gene responsible for color on the constitution of the moth--he posited the advantage of color in protecting the moth as a secondary selective force to explain why the spread had been limited to areas downwind of industrial areas. Again, the textbooks never tell you that, although Kettlewell inverted the relative importance of these two forces, even in his last published words on the subject he continued to contend that some other physiological affect of the *carbonaria* gene had played a role in its spread (Kettlewell 1973).

Regarding the seventh, as far as the evidence goes, most textbooks do not discuss the evidence Kettlewell provided at all. Those that do strongly suggest that the results were uncontroversial, which contrasts markedly with the actual reception of his investigations by his peers (Sargent, Millar and Lambert 1998). It is striking to note, for instance, that textbooks that do mention the details of his investigations mention his famous mark-release-recapture experiments, many suggesting erroneously in my view, that the experiments conducted in the

unpolluted wood were meant to serve as controls for the experiments conducted in the polluted wood (Rudge 1999, but see Hagen 1999). No mention whatsoever of the extensive observational field work he did, despite the fact that, in large measure, it was his films documenting birds preferentially picking off conspicuous moths that convinced many he had demonstrated that he had provided "Darwin's missing evidence" or direct evidence of natural selection.

In sum, the foregoing considerations suggest that textbook accounts are misleading to the point of raising serious concerns about the continued use of the phenomenon of industrial melanism as an example of natural selection. The simple, clear-cut manner with which textbooks recount the phenomenon, many of which introduce it as *the* best documented and best understood case of natural selection, contrasts markedly both with the historical details of Kettlewell's work and also continued controversies among scientists who actually work on the phenomenon. Jerry Coyne, a biologist who wrote a recent review of Majerus' book on melanism has gone so far as to claim that these problems completely undermine industrial melanism as an example of natural selection, and has openly called for its removal from textbooks (Coyne 1998).

The Import Of Problems With The Classic Textbook Account

What are we to make of these problems? Before going further I want to clarify that scientists who have actually done work on the phenomenon of industrial melanism still agree, despite these problems, that it is among the best documented cases of natural selection and that differential bird predation is undoubtedly the most important factor. Most of the debate centers around the relative importance of other factors in explaining the spread, such as differential migration and SO_2 concentrations (Berry 1990). The bottom line appears to be that an explanation of why melanic forms are becoming more common in some species may hinge crucially on the specific details of each case, and indeed, each population.

The question remains, however, what should we as science educators do in light of these developments? Majerus (1989) suggests these problems represent outstanding opportunities for teachers and students to conduct original and valuable research, particularly on species other than the peppered moth that have been the object of less work. There is undoubtedly something to be said for this approach, given the relative ease with which students can collect frequency data, the inexpensiveness of moth traps, and the ubiquity of the phenomenon. One can hardly dispute that actually doing science is the ideal way to learn about the design, execution and interpretation of the results of scientific investigations. Nevertheless, one can question whether this approach represents a realistic alternative, particularly for precollege students, given the extended nature of several of the projects he suggests and the scientific training it presupposes teachers have.

The balance of my talk will situate this controversy as part of a more general problem regarding the depiction of science for the purposes of science teaching. I will argue that the foregoing problems associated with how to portray the scientific study of the phenomenon of industrial melanism reflect a fundamental tension between the pedagogical task of introducing unfamiliar concepts and the need to accurately reflect the nature of science. Recourse to the history and philosophy of science, rather than just depicting science as a body of established knowledge, provides one avenue by which this tension can be negotiated without overwhelming the student with superfluous detail or unnecessarily undermining her confidence in the method of science.

The Pedagogic Advantages Of The Classic Account

While some simplifications reflect time and space constraints, teachers and textbooks alike omit many details out of a well-intentioned and steadfast conviction that students cannot understand science in all its complexity. Introductory students need simple, straightforward

descriptions and explanations in order to make sense of new terms and unfamiliar concepts. While some of the popularity of the classic account of industrial melanism reflects history and the fact that new textbooks often adopt familiar examples taken from older texts, it is fair to say that much of its ubiquity reflects several pedagogic advantages afforded by this particular example.

From the standpoint of heuristics, one would be hard pressed to find another example of natural selection that is as straightforward as the classic textbook account of the phenomenon of industrial melanism. It makes intuitive sense and refers only to elements with which teachers may readily assume students have some familiarity. The selective mechanism (bird predation) plays on the general view of natural selection as a struggle for existence. Moreover, the visual character of this example makes the spread of the melanic form and the selective differences between the two types of the moth in polluted and unpolluted settings easy to depict. Students can readily appreciate the visual contrast between dark and pale moths on lichen-covered and soot-darkened backgrounds as well as how birds preying upon moths might attend to these differences. Many other examples of natural selection are much more difficult to visualize (e.g. the evolution of pesticide resistance in insects).

It is important to note, at the risk of belaboring the obvious, that these heuristic advantages of the classic textbook account stem from its simplicity and the dramatic contrast afforded by the juxtaposition of photographs of the two forms of the moth taken from different settings. The inclusion of information on *insularia* or the removal of photographs from the account would seriously undermine the heuristic advantages of this example.

Similar remarks apply with regard to content. The relative simplicity and the absence of extraneous elements in the classic textbook account make it a particularly good vehicle with

which to teach the concept of natural selection. It discusses the simplest type of selection (directional) in terms of the spread of a single gene and one effect of that gene on fitness. Students can readily appreciate why and how visual differences between the moth in polluted and unpolluted settings would place the dark form at an advantage in one, and the pale form at an advantage in the other. Thus it is particularly helpful in clarifying relative fitness is a function of the fit between an organism and its environment rather than some reified property the organism possesses (Brandon 1990). Most other examples refer to more complex processes (e.g. heterozygote advantage in the case of sickle cell anemia) or appeal to effects of the environment on fitness that are less intuitive (e.g. snail banding patterns). We should note further that as a consequence of its popularity, many students already have some familiarity with this particular example from experiences outside the classroom. When we recognize that meaningful student learning is largely a function of the restructuring of existing knowledge (Novak & Gowin 1998), the advantage of using familiar examples is clear. Again, it can be argued that the addition of further detail, such as the possibility that other selective factors are at work, compromises the value of the classic account as a particularly lucid illustration by which to introduce the concept of natural selection.

In addition to explicating what a concept means, teachers often use a particular illustration to educate students about that example. And it is here that the debate among scientists noted above is particularly relevant. Coyne's point regarding the use of the classic account of the phenomenon of industrial melanism in introductory biology textbooks seems to be that textbook discussions of natural selection should mention or refer only to those examples that are well documented. Continuing to include the phenomenon of industrial melanism as the example of

natural selection constitutes a grave disservice to students, because by including it we tacitly suggest to students that it is a well understood example when it is not.

Without a doubt, there are other examples of natural selection that are better understood (e.g. the evolution of beak size in the Galapagos Finches). It is also fair to say that textbooks and teachers who use the phenomenon of industrial melanism should indicate that the phenomenon of industrial melanism may involve the operation of selection for factors other than color, and that it continues to be the object of ongoing research. But is it really the case that a textbook should never include scientific claims that are either suspect or known to be false? In the case of physics, the answer is decidedly no. We continue to educate students in Newtonian mechanics in full recognition that Newton's equations are technically false. One might argue that in the case of Newtonian physics, students are learning equations that are approximately true and moreover that such a step is necessary for them to understand and fully appreciate Einsteinian and post-Einsteinian developments. But the same could be said of the classic account of industrial melanism as well. While technically false, it is an approximately true story about how and why the phenomenon of industrial melanism has occurred that will no doubt be the background against which any more successful account will be based. The vast majority of students in high school and college do not go onto careers in evolutionary biology; for those that do, there is plenty of time in graduate school to learn the subtleties of this particular example. The many constraints on teachers and textbooks with regard to the time and space they can devote to the topic of natural selection, not to mention heuristic considerations, rally against the further stipulation that the accounts they provide must be true or command consensus among scientists. The problem is not that textbooks and teachers are knowingly perpetuating falsehoods, but rather the uncritical and unreflective attitude students (and teachers) take towards the information

gained from such sources. Rather than presenting the phenomenon of industrial melanism as a subject that was settled by three field experiments by H.B.D. Kettlewell in the 1950s, both teachers and students could profit from thinking about this phenomenon as the object of ongoing scientific attention (Grant 1999).

The aforegoing considerations point to another, often neglected, advantage afforded by the overly simplistic textbook account of industrial melanism. It has long been recognized that students should be learning about the nature of science as a process (DeBoer 1991). Teachers can use the pithy description of Kettlewell's initial work associated with the standard account to introduce students to how scientific claims are developed and tested in science. Kettlewell's mark-release-recapture experiments are elegant in their simplicity and involve only a minimal amount of mathematics. Having a simple, clear-cut example of how scientific claims are investigated provides a wonderful introduction to the process of science. Inclusion of the many interpretive problems now associated with Kettlewell's experiments conversely limits their value in introducing the logic of science by making the results ambiguous.

A Role For The History Of Science

Teachers and textbook writers are, of course, familiar with the above tension. Unfortunately many interpret this as a debate that must be decided one way or the other: either we must focus on pedagogical considerations of how to make science accessible to introductory students *or* we must provide students with an accurate description of the nature of science and what we know about the world. Most teachers choose the former, and it is hard to blame them given the stress placed on preparing students for standardized tests on isolated concepts, limitations of time and resources, and their own lack of scientific training. Textbooks, which often define the curriculum for science classes, further the perception that learning science is a

matter of memorizing a set of idealized claims and definitions. While teachers recognize that ideally they should be educating students about the complexities of science, one can well appreciate why for many this seems to be a luxury that they can ill afford.

We should recognize, however, that this is a false dilemma. There are ways of teaching science that can both provide students with simple, accessible illustrations of scientific concepts and also share some of the complexities of the actual practice of science. Part of the solution will depend upon revising standardized tests to focus less on content and the refinement of teacher training programs to do more in the way of training them in the actual practice of science. But part will also depend upon the development of superior instructional materials and lesson plans that go beyond just teaching the basics. And it is here, I suggest, that the use of history of science, as illustrated by work on industrial melanism, can play a pivotal role.

It has long been recognized that discussing scientific debates with reference to their historical and philosophical contexts provides an excellent vehicle with which to promote active learning about how scientific claims are developed and evaluated (Matthews 1994). Joel Hagen (1993, 1996) has shown how Kettlewell's investigations in particular can be used to promote active learning. Discussing the history of work on the phenomenon of industrial melanism in a broader context can further help students become aware of how patterns in nature are discovered, how models are used to explain those patterns, and how such models are evaluated.

As noted in the brief outline of the standard account above, the history of work on the phenomenon of industrial melanism provides students with a wonderful example of how a curious pattern was discovered in nature by lepidopterists, naturalists and amateur moth collectors. The teacher can discuss with students how discoveries of rare dark forms of certain moths such as f. *carbonaria* in the peppered moth, *Biston betularia*, were initially identified as

occasional accidents of nature. She can then point out how the increasing frequency with which these forms were found led individuals who found them to notice a pattern in their distribution: an odd association with areas downwind of industrial sites. The beauty of this example is that recognition of the pattern does not depend upon a previous scientific context per se.

Discussing the history of work on the phenomenon of industrial melanism also provides teachers with an opportunity to discuss how models are developed and used in science. From a constructivist perspective, meaningful learning involves the restructuring of previous knowledge. Teachers must elicit what the students already know about a subject if they are to correct antecedent understandings and/or misconceptions students bring in to the classroom. Students without previous training in evolutionary biology often have strong intuitions that closely resemble Lamarckian or mutationist perspectives (Bishop and Anderson 1990). In the case of the phenomenon of industrial melanism, there are excellent historical precedents to both these perspectives- both Lamarckian and mutationist interpretations of the phenomenon were seriously entertained as potential explanations (e.g. Cooke 1887, Heslop Harrison 1927). Teachers can likewise discuss this example with reference to natural selection, and, as noted above, the phenomenon of industrial melanism is a particularly helpful illustration precisely because it provides a straightforward and intuitive example of this otherwise unfamiliar and difficult concept.

In the presence of three distinct models offered as explanations of the pattern, teachers can press students to consider whether one model might be a better explanation than another. Here recourse to the evidence that historically led Kettlewell and other biologists since to dismiss Lamarckian and mutationist theories is one important avenue by which meaningful learning can take place. Discussing the variety of observational and experimental studies Kettlewell used to

discredit other models and support his own illustrates to students how models are tested in science. The almost unique advantage of early work on the phenomenon of industrial melanism for teaching in this regard is that Kettlewell's investigations were elegant in the simplicity of their design and involve a minimal amount of mathematical reasoning. These aspects make discussion of experimental work in this context much more accessible to students than experimental and observational studies used in support of other examples.

Monk and Osborne (1987) have pointed out that successful use of history and philosophy of science in the teaching of science requires some sense of closure to the discussion. High school students are notorious for dualistic thinking and a need for knowing what the "right" answer is; a phenomenon not unknown among college students. Teachers who are convinced their students have such limited intellectual capabilities should, in my opinion, feel free to end the discussion by pointing out that on balance the evidence favors Kettlewell's interpretation by minimizing or omitting details of the outstanding problems noted above. The phenomenon of industrial melanism is without a doubt an example of evolution by natural selection and the suggested requirement students must have complete knowledge of all the outstanding scientific questions surrounding this particular example is overstated.

The problem with such an approach is *not* that it leaves students uninformed about our current understanding about the phenomenon of industrial melanism. The problem is that it perpetuates a stereotype of science as a body of knowledge. Students would be much better served if they left our classrooms with some questions that left them thinking, rather than a tidy answer to be forgotten once the test is over. Discussing some of the contemporary controversies surrounding the phenomenon of industrial melanism with students will help them better

appreciate the nature of science, the tentative nature of scientific knowledge, and the complexity of the process of science.

Note it is the presence of discrepancies between the classic textbook account and what is actually known that makes the phenomenon of industrial melanism so valuable for the purposes of science teaching. By contrasting the oversimplified version with a richer account of the history of work on the phenomenon, teachers can drive home the differences between science as it is depicted in textbooks and the practice of actual research. The fact that our current understanding contrasts markedly from the classic account makes it all the more intriguing. Indeed one could argue that if there were only slight differences between the two accounts, the distinction would be too subtle to be appreciated by the vast majority of students. Thus, the current controversies surrounding the phenomenon of industrial melanism, far from undercutting its importance, actually augment its value for the teaching of evolutionary biology.

This example can also help disabuse students of identifying experimental work as the hallmark of science. By pointing out the importance of ecological and life history data to ongoing debates about the evolution of melanism, teachers can underscore the complex interplay between observational and experimental studies in the life sciences (Rudge 2000b).

Conclusions

Let me now summarize what I've been discussing with you. I began by briefly reviewing several discrepancies between textbook accounts of the phenomenon of industrial melanism and our current understanding of both the phenomenon and Kettlewell's work on it. There are some, such as Jerry Coyne, who've argued that the presence of these sorts of discrepancies completely undercuts the use of the phenomenon of industrial melanism for use in teaching about natural selection. In contrast to Coyne, I've argued that the classic account remains an excellent vehicle

by which to introduce students to the concept of natural selection, and moreover, that by discussing the history of work on industrial melanism--and in particular discrepancies between the classic account and our current understanding--that students can gain insight into the nature of science as a process.

Note

This paper is based on Rudge 2000a.

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INTEGRATING TECHNOLOGY INTO TEACHER PREPARATION AND K - 12 CLASSROOMS

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Technology Advancing a Continuous Community of Learners

The Technology Advancing A Continuous Community of Learners (TACCOL) project at Clarion University was awarded a grant in the amount of $455,500 funded by the Link-to-Learn Higher Education Initiative, "Integrating Technology into Teacher Preparation," from February 1999 through June 2000. Dr. Vickie Harry, Education Department, and Dr. R. Elaine Carbone, Mathematics Department, are the Co-Directors of the project. TACCOL developed and implemented an innovative environment for interfacing technology with mathematics and science education while achieving and maintaining systemic change in teacher education and K - 12 learning. The goal of the project was to provide professional development for higher education faculty, prospective teachers, and practicing teachers (cooperating teachers from area school districts) to enhance instruction in mathematics and science through the use of computers, graphing calculators (TI-73, TI-89, TI-83+), Calculator Based Rangers (CBRs), Calculator Based Laboratories (CBLs), and multiple probes while sustaining a continuous community of learners.

Through the infusion of technology in the mathematics and science curricula, a hands-on, activities-based approach to teaching and learning was presented to university faculty, prospective teachers, and practicing teachers through their attendance and participation in TACCOL graduate classes at Clarion University. Faculty in the Departments of Education, Mathematics, Physics, Biology, and Chemistry modeled a technological approach to the teaching

and learning of science and mathematics for all three populations through learner-centered instruction.

Professional Development

During the 2000 - 2001 year, 30 higher education faculty, 135 practicing teachers, and 152 prospective teachers learned technology competencies as they connected mathematical and scientific concepts while engaged in real life investigations. Through the underlying theme of collecting real data and analyzing the results, the TACCOL faculty modeled strategies interfacing technology with the teaching and learning of science and mathematics.

Thirty university faculty participated in morning sessions for one week in May 2000 to learn to integrate technology into college classrooms. One hundred ten classroom teachers participated in weeklong, all day classes in July 1999 and a second group of twenty-five classroom teacher attended the same classes in July 2000. Prospective teachers in elementary and secondary mathematics and science methods classes were also introduced to the technology competencies learned by the university faculty and practicing teachers.

Collaboration Between the College of Arts and Sciences and the College of Education

The collaboration between the Colleges of Arts and Sciences and Education and Human Services during this project has been outstanding. A team of six faculty members from the Departments of Education, Mathematics, and Physics designed and implemented the professional development activities for the TACCOL participants. This paper will present the collaborative activities of a mathematics educator in the College of Arts and Sciences and a science educator in the College of Education and Human Services describing how they continued

to plan and implement mathematics and science learning experiences that integrated technology into classroom practices with K - 12 teachers.

Elementary Activities

Two graduate assistants in the Master of Science Education degree program who had achieved K - 6 teacher certification in Pennsylvania enrolled in the TACCOL workshop during the summer of 2000. They designed an activity integrating mathematics, science, and technology using hands-on, easily obtainable materials. The two teachers are currently employed by the Department of Defense Dependents Schools (DoDDS) in Japan and Korea. The activity, Endothermic and Exothermic Reactions, is described below.

The lesson background includes the following content information. Chemical and physical changes are accompanied by energy changes, usually in the form of heat energy. Heat energy can be liberated or absorbed; for example, the absorption of heat energy by evaporation is responsible for the cooling effect felt when water evaporates from skin. When heat energy is liberated, the process is exothermic. On the other hand, when heat energy is absorbed, the process in endothermic. The objectives for the lesson are:

1. Separate contents of heat and cold packs.
2. Give each group 1 cup of Magnesium Sulfate, cup of Ammonium Nitrate, and 2 beakers of water.
3. Connect the CBL to the TI 73 and the temperature probe.
4. Measure initial temperatures of the of the water.
5. Record the initial temperature of the water.
6. Set up data logger and

7. Set recording time at 60 seconds.
8. Mix (begin data logging) one of the solutes with one of the solvents and note the temperature changes over time.
9. Interpret, discuss, and record the results.
10. Trace to see temperatures at specific times.
11. Repeat the steps with the remaining materials.
12. Explore possible uses and real-life applications.
13. Reveal the mysterious solutes and solvents.

Materials needed to complete the activity include TI 73 calculators, CBL packages with probes, safety glasses, ammonium nitrate (Instant Cold Pack), magnesium sulfate (Instant Hot Pack), 250 ml clear beakers, stirring rods, paper cups, and water. (The hot and cold packs may be purchased at pharmacies for about $.95 each.)

Other Grant Opportunities

As a result of the interactions between the university faculty and the practicing teachers, two additional grants were written and funded. The funding source for the two projects described below was Advancing the Development of Educators in Pennsylvania through Technology Training (ADEPTT). One grant project, Establishing and Maintaining an Elementary Website for Redbank Valley School District (RVSD), received an award in the amount of $5,000 to achieve the following objectives.

1. Students, student teachers, and teachers will gain mastery of web authoring software and graphic tools as they construct the website.

2. Students will view and evaluate websites created by other schools, using the information gained from this evaluation process and their own critical thinking skills to decide which topics would be appropriate for use on their website.
3. Students will develop teamwork skills including research, design, communication, and organizational skills.
4. Students, student teachers, and teachers will maintain and improve the website for Redbank Elementary School.

The second grant project funded by ADEPTT entitled, Investigations and Inventions with Robotics, also received an award in the amount of $5,000. The North Clarion Elementary School received robotics equipment for the elementary school technology lab to be used to accomplish the following objectives.

1. Build and design robots and robotics programs.
2. Download programs from the computer to the robots via infrared transmitters.
3. Collect and log data for the purpose of analysis and interpretation.
4. Utilize the internet and reference software to discover how robotics applies to real life situations.
5. Work as a team to achieve success in problem solving.
6. Create digitized images of learning experiences and robotics creations.
7. Display images on the North Clarion Elementary web site on a page for students generated projects.

The teacher education majors from Clarion University who are placed at North Clarion Elementary School for pre-student teaching and student teaching experiences will also learn to use the equipment.

Secondary Activity

An activity with the Calculator Based Laboratory (CBL) and a light sensor was demonstrated during the session that was used in the training of the practicing and pre service teachers. The Jump program from Texas Instruments web site (http://www.ti.com/calc) was loaded on a TI-83plus calculator to introduce the CBL and the light sensor. The program is very user friendly giving directions on the screen of the calculator in setting up the CBL and the light sensor for a jump activity. The light sensor was aligned with a flashlight so that the beam of light from the flashlight focused on the light sensor. The light sensor was connected to the CBL, and the CBL was connected to the calculator. A participant in the session volunteered to perform a vertical jump by standing in the beam of light, and then broke the beam when he jumped vertically. The calculator analyzed his hang time in the air and then calculated the height of his jump. Then there was a discussion of whether a "real" vertical jump was necessary to receive an output of inches jumped on the calculator. The scientific experiment of merely breaking the beam with ones hand and simulating a jump was performed. The calculator gave a "Jump error." Did the calculator know that a jump was not performed? A discussion followed that the program must have a maximum value similar to a real jump that one could wait before breaking the beam the second time. The demonstration showed that the calculator would calculate a high jump, if one carefully timed how long they waited to break the beam for the second time.

The Jump example was used in the training of the practicing and preservice teachers. It gave these groups the opportunity to have a hands-on experience with the technology while discussing a scientific experiment that also gave quantitative data to analyze. Box plots of the data from the teacher groups was shared. A comparison of box plots of male and female mathematics faculty jump data was shared. The analysis of the data from a scientific experiment led to teaching mathematical concepts, and further discussion of those concepts.

Conclusion

Professional development activities using technology as a tool to integrate science and mathematics for prospective teachers, practicing teachers, and teacher educators must happen simultaneously. These activities continue as student teachers are trained by the university faculty and are placed with the teachers who also learned the technology at the TACCOL classes. The university faculty, while supervising the student teachers, continue to have opportunities to collaborate with the practicing teachers. The Clarion University ITTP project is a successful model exemplifying a continuous community of learners.

TECHNOLOGY : PRESERVICE TEACHERS' PREPARATION : : OIL : WATER

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Few, if any, would dispute the statement that technology is an integral part of everyone's daily life. Computer viruses shut down businesses, library collections are accessed via databases, even grocery stores use scanners and computers to determine a customer's charges. The Goals 2000: Educate America Act (Goals 2000, 1994) includes technological applications in elementary and secondary schools. The National Science Education Standards (National Research Council, 1996) stress the need for students to be able to use appropriate technology to gather, analyze, and present data. The National Council of Teachers of Mathematics (2000) states "technology is essential in teaching and learning mathematics" (p. 24). Deciding if, when, and how technology can be used in the classroom to enhance learning is the responsibility of the classroom teacher. Are our classroom teachers being prepared to be able to make these decisions?

A report by the President's Committee of Advisors on Science and Technology (1997) indicated that the majority of teacher preparation programs nation-wide was not preparing teachers to effectively use technology in K-12 classrooms. The Milken Study (Moursund & Bielefeldt, 1999) confirmed this finding. In response to this shortcoming, local, state, and national standards have been developed to help determine what teachers need to know about the effective use of technology for enhancing learning (Barnett & Lenhardt, 1998). The National Council for Accreditation of Teacher Education (NCATE) has adopted the curriculum guidelines of the International Society for Technology in Education (ISTE) (International Society for

Technology in Education Accreditation Committee, 1998) and has included these technology standards into its accreditation requirements (NCATE, 1997). Several studies have attempted to ascertain why technology preparation for preservice teachers is minimal (Murielle, 1998; Parker, 1996; US Congress, Office of Technology Assessment, 1995). Others have reported on ways in which institutions have address this problem (Bednar & Charles, 1999; Levin, 1999; Metze, Jayes, Eakles & Murley, 1998; Pedras & Horton, 1996; Parker, 1996, Grau, 1996; Zhao, Rop, Banghart, Hou, & Topper, 1998). All agree there are two essential components to adequate instructional technology preparation: preservice teachers must not only be able to use the technology themselves, but they must be instructed in and actually practice using the technology in K-12 classroom activities. The question remains: Have teacher preparation programs, particularly in the areas of mathematics and science, modified the way they prepare preservice teachers to use technology?

In an attempt to gain some insight into this question, we focused on the teacher preparation programs in the State of Oregon. Oregon has 16 higher education institutions offering programs leading to teaching licensure. These programs may be a four-year undergraduate program or a fifth year graduate program, wherein the entrant has attained a Bachelor's degree prior to admission. As in most states, Oregon K-12 students are assessed according to a statewide system of standards. Consequently, it is important for teachers to have a solid background in mathematics and science to assist their students in meeting the state benchmarks in these content areas. Oregon does not have specific technology requirements for teacher licensure. For the purposes of this study, technology is being limited to electronic technologies; that is, calculators and computers.

A recent survey conducted by the Oregon Collaborative for Excellence in the Preparation of Teachers (OCEPT) (Wainwright, 2000) asked the 16 teacher preparation institutions to respond to a series of questions concerning mathematics and science content and pedagogy preparation. It also included two questions on technology: what, if any, expertise was required of students entering the teacher preparation program; and what experiences with technology were included in the teacher education program. While all the institutions canvassed replied to the survey, only half of the institutions responded to the technology items. Typically, students were expected to have minimal computer competency (word processing, ability to access the Internet), although courses for attaining such competency were offered for those in need. The answers to the second question were vague. Most institutions required students to take some type of instructional technology course. What exactly is covered in these courses was not explicit.

Little is still known about how preservice teachers are being prepared to use technology with their students. The purpose of this study is to begin to determine to what kind of instruction, modeling, and pedagogy involving technology in the mathematics and science content areas the preservice teachers are being exposed .

Methods

To collect data on technology preparation and use by preservice teachers, an open-ended survey was designed based on the recommendations of other studies (Moursund & Bielefeldt, 1999; US Congress, Office of Technology Assessment, 1995; Northrup, 1997; President's Committee of Advisors on Science and Technology, 1997) and the proposed standards drafted at the National Technology Leadership Retreat (Flick & Bell, 2000; Garofalo, Drier, Harper, Timmerman & Shockey, 2000). The questions were as follows:

1. What technology skills do you expect of students before they enter science/math methods courses?
2. What training in using electronic technology do you perceive students are receiving in math and science content courses?
3. How do you model uses of technology in your methods courses?
4. Are preservice teachers required to incorporate uses of technology in lesson plans?
5. In the past five years, have you changed the content of your science/math methods courses to assist students in employing technology in their field classrooms? If so, how?

The only identifying information on the surveys were the institution and the levels of authorization (Early Childhood/Elementary or Middle/High School) of the methods course. Surveys were sent to the mathematics and science methods instructors at the 16 teacher preparation institutions in the State. A cover letter explaining the purpose of the study and defining electronic technology accompanied the survey.

Results

Eighteen methods instructors representing nine teacher education institutions returned the survey(s). Of these, 11 surveys represented Early Childhood/Elementary courses and 11 were for Middle/High School courses. (Several instructors taught multiple authorizations levels.) The findings were analyzed on an institution-by-institution basis, and by authorization level.

Since preservice teachers are likely to have had substantial experiences with technology prior to their math and science methods courses we asked what technology skills methods instructors expected of their students before they entered the methods courses. Almost every respondent indicated expectation of skills in being able to find information on the internet and

word processing (Table 1). Fewer instructors listed skills in using email and calculators. Additionally presentation tools and spreadsheets were mentioned.

Table 1
Technology Skill Expectations

	Internet	Word Processing	Email	Calculators	Spreadsheet	Presentation Tools
Early Childhood/Elementary	10	10	7	6	2	3
Middle/High School	9	8	7	7	2	2

Respondents were also asked what training in using electronic technology they perceived students were receiving in math and science content courses. Six ECE/Elementary methods instructors listed calculators—three responses were listed as graphing calculator specifically. Eight Middle/High instructors listed calculators with seven listing graphing calculator specifically (Table 2). Although a variety of other technologies were listed, none more than 3 times. One ECE/Elementary respondent indicated students should have had discussions about appropriate uses of technology and one Middle/High School instructor indicated students should have had *a great deal* of training with electronic technology from their math and science content courses.

Table 2
Math/Science Course Technology Training

	None	Calculator*	Simulation	Internet	Spreadsheet	Graphics	Databases	Logo	Presentation Tools
Early Childhood/Elementary	3	6(3)	1	2	3	1	1	1	0
Middle/High School	1	8(7)	1	3	3	1	1	0	1

*Numbers in parentheses note specific mention of graphing calculators.

Various authors have linked technology use by teacher education instructors to preservice teachers' eventual use of technology in their own classrooms (President's Committee of Advisors on Science and Technology, 1997). In our study we attempted to gauge faculty technology use through asking how instructors modeled technology use in methods classes. About a third of the respondents answered this by describing how their students used technology in class. These were predominantly Middle/High School level instructors. While this exposes other students to the use of technology and is a positive practice, it does not fit the definition of instructor modeling.

Faculty who did describe their own use of technology listed activities in three areas—in-class uses, preparation for class activities and uses of technology in communicating with students (Table 3). Although preparation and communication activities were similar for instructors at all authorization levels, ECE/Elementary teachers listed a wider variety of ways in which they modeled uses of technology in class.

Table 3
Faculty Technology Use Modeling

	In-Class	Preparation for Class	Communication
Early Childhood/ Elementary	Calculators (Graphing, Overhead Calculator), Video/Audio Materials, Library Training, Software Review, PowerPoint Presentations, Discussion of Web Sites, Internet Resources, CD ROM Resources, Computer Lab Class Sessions	Listing of Internet Resources, Preparation of Handouts	Email, Listservs, Attachments
Middle/High School	Software Review, PowerPoint Presentations, Show Programs, Internet Resources, CD ROM Resources, Graphing Calculator	Listing of Internet Resources, Preparation of Handouts	Email, Listservs, Attachments

As a measure of the degree to which preservice students applied technology training beyond the methods classroom, respondents reported whether preservice teachers were required to incorporate uses of technology in lesson plans. Responses were similar for all authorization levels. Responses were equally divided between requiring and not requiring incorporation of technology in lesson plans (Table 4). It was noted in many cases that incorporation of technology in one lesson plan would suffice to meet this requirement. Three respondents indicated a technology component was required in *some cases*. The meaning of "some cases" was nebulous.

Table 4
Lesson Plan Technology Incorporation

	Required	Not Required	In Some Cases
Early Childhood/Elementary	4	6	1
Middle/High School	4	5	2

Like all educational institutions, teacher education programs change conservatively in an attempt to incorporate new best practices while avoiding less productive trends. For this study we asked methods instructors *in the past five years, have you changed the content of your science/math methods course to assist students in employing technology in their field classrooms? If so, how?*

At the ECE/Elementary level four respondents indicated the methods courses had not been actively changed. One said no changes had been made, one indicated they were planning to, and two indicated the course had changed indirectly because students brought more technology skills to the course. At the Middle/High School level three respondents indicated no changes had been made, one because the program was new.

Reported additions to methods courses included specific activities and general topics (Table 5). The responses were similar at all levels. Some of the courses which have changed the most were listed by respondents who were reporting across all four authorization levels.

Table 5
Methods Course Technology Additions

	Specific Skill Additions	General Topics
Early Childhood/ Elementary	WebQuest, Calculator and Computer Use, PowerPoint, Finding Web Based Resources, Email, Excel	Technology Based Tutoring, Electronic Resources, Web Based Instruction, CD ROM Resources
Middle/High School	PowerPoint, WebQuest, Graphing Calculator, Grade Books, Web Based Resources, Email, Excel	Electronic Resources, Appropriate Uses of Technology, Computer Based Learning, CD ROM Resources

Conclusions and Implications

The data indicate there is a uniform expectation that preservice students will have basic computer skills when they come to methods courses (word processing, email, Web based searching, and calculator use). Our findings mirror those of Wainwright's (2000) earlier study reporting on expectations of students being admitted to teacher preparation programs. However, there is no clear indication of where the students may have obtained these skills and there may be no pre-assessment of the degree to which they have mastered these skills prior to entering a methods course. In Wainwright's (2000) study, several institutions indicated that students lacking in these technological skills are able to take courses to gain them, although the courses are not required.

The predominant technology identified as an expectation of science and/or mathematics content course preparation is the calculator, and, more specifically at the Middle/High School level, the graphing calculator. This expectation does not match what the preservice students have reported. In an Oregon state-wide survey of students enrolled in teacher preparation programs (Morrell, 2000), 57% of Early Childhood/Elementary undergraduate students reported using graphing calculators in a mathematics course and 13% in a science course. Of students enrolled in a fifth year (MAT) Early Childhood/Elementary program, 39% reported using graphing calculators in a math course and 11% in a science course. As would be expected, the percentages for those undergraduates and MAT students seeking to teach mathematics or science in the Middle/High school were higher: 64% in math courses and 22% in science courses. Science and math methods instructors may have unrealistic expectations of their students' expertise with this piece of technology.

It is not clear that methods instructors uniformly model the use of electronic technologies or require their students to apply them in methods courses. Modeling of technology is not consistent. Instructors varied considerably in the types of technology they used with the preservice teachers, although instructors consistently used internet based resources and communicated with their students electronically. Because modeling may have a causal effect on students' eventual use of technology in their field classes, a lack of modeling by methods instructors seems a serious issue and one worthy of further inspection.

For the most part, preservice teachers are not being expected to incorporate the use of electronic technology in their teaching on a regular basis. Only half of the methods instructors required any technology to be used; and in many of those cases, one use met expectations. It is unlikely that preservice teachers will develop habits of use of technology in their classrooms without the opportunity to practice same in their preparation programs.

It is interesting to note that in the few cases where multiple responses were received from individual institutions, the methods instructors did not respond similarly to all questions. This implies there is a lack of consistency within programs as well as among programs.

Not surprisingly there appear to be three general levels of technology use in mathematics and science methods courses. At one level a few instructors incorporate technology in very limited ways. At a second level, although most instructors are attempting to incorporate an increasing focus on technology-based activities, these activities are idiosyncratic. Finally, a few instructors have revised their courses to incorporate technology systematically and comprehensively. This variation may be an indication that programs are revised to incorporate technology based on instructor preferences rather than either curriculum guidelines or national standards.

Based on this limited study of the incorporation of technology use in mathematics and science methods, it would appear that technology has not been uniformly incorporated into preservice teacher preparation. It still stands as a part separate from the whole. Technology is to preservice teachers' preparation as oil is to water.

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USING ELECTRONIC CLASSROOMS AND THE WORLD WIDE WEB TO SUPPORT SCIENCE TEACHING AND LEARNING: INTERACTIVE SESSION SUMMARY

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Recently, Colleges of Education across the nation have been charged with infusing computer and information technologies into their teacher education programs. This charge has mainly come through accreditation organizations such as INTASC and NCATE. Essentially, colleges that seek reaccreditation must meet standards that include computer and information technologies in significant ways in teacher preparation and professional development programs.

One rationale for this charge is that these technologies are finding increasing use in the schools in which preservice and inservice teachers work. Meeting the charge of the accrediting organizations can also be seen as relevant to what teachers are experiencing in the workplace. School districts want teachers who can use technology to maximize learning opportunities for students.

As a result of these two factors, science teacher educators must model how technology can be infused into the classroom culture. Some have been using the World Wide Web as an instructional resource room, posting syllabi and other materials and establishing links to specific web sites. Others have worked to create more interactive situations that mirror and extend the classroom environment, including both interactive and management aspects of a course. Of late, the development and proliferation of more complex web-based courseware has made interactivity more possible for professionals

who lack extensive computer programming experience. In some situations, teacher educators are using this technology to catalyze and monitor discussions and other interactions around critical issues in teaching and learning.

Each of the presenters in this panel has used a different approach for creating and using web-based course enhancements. Michael Beeth received training in MS Front Page, and has utilized web pages for syllabi, and links to other course-related resources, for several years. Marcia Fetters, with no formal training in Web design and programming, has used the free Nicenet courseware extensively, for management as well as interaction. Paul Vellom has used web resources in methods courses for several years, and recently attended a WebCT workshop and began using WebCT courseware to extend preservice teachers' learning around critical issues such as classroom management. The presenters discussed these uses of the Web, and then started a conversation with participants about the use of on-line classrooms and materials, with the goal of understanding both the potential and the limitations of using the Web in science teacher education.

Making the Web Work as a Resource

Beginning a couple of years ago, Dr. Beeth has developed web pages for each of his course syllabi, so that they are generally available to his students at any time. Over time, he has reworked these syllabi each time a set of courses is complete, mainly adding links to such web-based educational resources as, 1) the Eisenhower National Clearinghouse for Science and Mathematics Education and the ERIC Clearinghouse for Science, Mathematics, and Environmental Education, 2) sites for electronic journals and proceedings from research and teacher conferences, 3) sites which describe and extend

community-based resources, and 4) sites having to do with specific science topic areas such as genetics, ecology, or electricity. In addition, Michael has increasingly utilized electronic formats for submission of student work and for communications with students. Dr. Beeth stated that his first effort of getting a lot of materials available on the web then led him to think more about interactivity. Those first materials weren't very interactive, and this led him to think about creating that interactivity, both in the websites he designs and in finding other resources for teacher education. He discussed some of the successes and barriers that he has encountered in using the web effectively as an instructional resource in preservice, inservice, and doctoral programs.

A Home on the Web

Creating an on-line classroom/course became a doable reality for this instructor after hearing Dr. Jack Hassard from Georgia State University describe how he used a free service called Nicenet to create on-line classrooms to support his students. At this conference a variety of ideas were shared with middle and high school science teachers about how this could be made an integral part of teaching and learning.

Nicenet's Internet Classroom Assistant (version 2)(ICA2) was released in 1998, and billed as a "free web-based learning environment for classrooms, distance learning programs and collaborative academic projects"(Nicenet, 1998). The press release provided the following information about the ICA: "a sophisticated communication tool that brings powerful World-Wide-Web based conferencing, personal messaging, document sharing, scheduling and link/resource sharing to a variety of learning environments. Nicenet provides the ICA free of charge with no advertising.

The ICA runs on Nicenet's server and requires a web browser running on any platform and an Internet connection - there is no software to download and no server to configure. The ICA was intentionally designed as a low graphics environment to decrease the load time of each page. The queries used to fill the site with class-specific data take less than a second. A fully dynamic site, the ICA is customized at two different levels: 1.) the user and 2.) the class. Anyone can set up a class in minutes and allow others to join. After login, users are presented with a "heads-up" display of class resources."

Unlike some of the more powerful on-line courseware, Nicenet does not support graphics, nor does it support on-line chat rooms. While to some this may be disappointing, this is also one of it's strengths. Individuals with lower-end machines or slow modems can have easier access to the web site and associated materials.

Setting up a class is quick and easy, and takes just a few minutes. Once you have set up a class you receive an e-mail that has your "class key" in it. Have students go to the Nicenet website and join the class. They will be asked for the class key and to set up a Nicenet identity. A nice part of this is the instructor doesn't have to enter the student information!

Handling Critical Issues in Teaching Using the Web

This panel member presented a brief overview of his experience teaching a preservice methods class over two years. During the first year, the web was used as a resource for information in several areas, including examples of lessons, current research on teaching and learning in specific science topics, and community-based resources. During this same year, in-class discussions of critical issues in teaching (such as assessment, classroom management, and the impact of standardized testing) were often

dominated by a few individuals. While Dr. Vellom held goals of all students engaging in thoughtful reflection leading to informed decisions on these issues, it wasn't happening.

In the second year, WebCT was introduced stepwise as a management tool, as well as to extend and monitor classroom discussions of critical issues. Threaded discussion was initiated on these issues, with the following benefits: 1) level playing field in which all were required to participate, and those who normally dominate in-class discussions were limited by a class maximum of 5 postings, 2) thoughtful initial responses (for the most part) covering more ground than typical in-class responses, 3) many students got responses to their initial postings, and these were mostly positive, 4) instructor was able to monitor breadth and depth, and consider carefully before responding to individuals or the group. Some limitations of this approach were also shared: 1) some students had difficulties related to Web use, such as finding/making time or logging on incorrectly, 2) some very good initial postings that dealt with important issues were not the object of responses, 3) the discussion did not occur in real time, so the instructor was not aware of 'context clues' that can be important in a face-to-face encounter.

WebCT (Web Course Tools) is commercially available, and can be used for online courses as well as course enhancement. Each WebCT course has the following built-in features: 1) a welcome page, accessible to any web user, 2) username identity system used to give students access to all course in which they are enrolled, 3) areas for course content (lecture hall), and 4)areas for links to other URL's, interactive modules using flash, etc.

Web CT communication tools include synchronous (chat, whiteboard) and asynchronous (email, discussion forums, student presentations, student web pages). WebCT also includes student management functions, including online quizzes with scoring functions, a gradebook with student reporting functions, and student tracking for page use, time, and postings to forums.

Course management functions include TA or co/teacher access, and chat and discussion forums can be compiled and downloaded as text files for research, etc.

Discussion forum use: The Assignment

I asked students to pick a memorable event from the introductory general methods course and to tell why it was memorable. I asked that they then create a balanced analysis with costs and benefits, and tell what they would do as a result of the activity or event. Also, in order to facilitate good discussion, I required each student to make one initial posting and one response to a posting, with a maximum of 5 postings.

Discussion forum use: What happened:

Fifty seven out of 58 students were able to post with no additional help from the instructor. To a large degree, the initial postings mimicked earlier non-web reflective writings (see framework below). In their responses, students were polite and caring (mostly). However, analysis revealed very little evidence of moving beyond the specific task on initial use, i.e. no synthesis of a discussion thread, etc. One student chose to criticize others for incorrect thread issues (very few of these).

Other course evaluations revealed:

Thirteen of 58 students marked WebCT as the best part of the course. When asked specifically about WebCT discussions, a common theme was the desire for

instructor participation, validation, and feedback. A teaching principle that emerged from this experience: structure interactions carefully to get what you want from your students

Implications

This interactive session was designed to assist us and others in meeting the challenge to infuse technology into science teacher education. The WWW presents opportunities to change practice in science teacher education to better address the needs of preservice and inservice teachers, and to reflect the reality of the increasing use of computer technologies in teaching and learning environments.

References and WWW Resources:

Nicenet (1998). http://www.nicenet.org/ica/ica_info.cfm

http://www.nicenet.org/

http://webct.com

http://enc.org

http://ericse.org

http://www.gsu.edu/~mstjrh/mindsonscience.html

http://www/blackboard.com/

THE PHILOSOPHY, THEORY AND PRACTICE OF SCIENCE-TECHNOLOGY-SOCIETY ORIENTATIONS

Chris Lawrence, The Florida State University
Robert Yager, University of Iowa
Scott Sowell, The Florida State University
Elizabeth Hancock, The Florida State University
Yalcin Yalaki, The Florida State University
Paul Jablon, University of Massachusettes at Lowell

Philosophy and Praxis

If Science, Technology, Society (STS) orientations are fully understood and implemented they can serve to integrate the many facets of science education reform such as those proposed by the National Science Education Standards and Project 2061. While other orientations could also facilitate this integration, STS orientations have historically characterized student development on a more holistic and philosophical level than other current perspectives and take into account the broader concerns of the science curriculum, student development, and teacher development. However, it seems that guiding frameworks have not been as fully developed that can serve as a strong basis for these approaches, especially in advancing further research and practice. Or the problem may be in getting the theoretical frames and practice together as praxis, "that ideal dialectical interplay between theory and practice, which is the basis for critical, reflective action, [which] can arise neither in the classroom nor in the exigencies of direct practice, but only in the relation between them (Lemke, 1994, p. 4)." We might add philosophical to Lemke's definition as the broader factor that helps bind together and interpret the three (Figure 1).

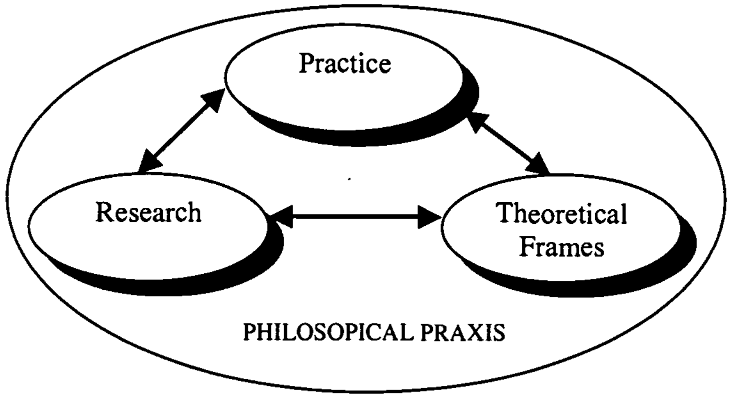


Figure 1: Philosophical Praxis as the Interplay of Research, Practice, and Theoretical Frames

This praxis is meant to include university level science educators, teachers in K-12 classrooms, preservice teachers, and graduate students in science education. A focus of this paper is in developing shared philosophical practice that brings different communities together as a starting point in researching, practicing, and theorizing about STS orientations to the curriculum. So many have contributed to the discussions and writing that we find it hard to adequately give them credit. This paper describes the evolving discussions and key considerations in understanding and promoting STS orientations through these communities.

Evolving Praxis: Graduate Level Coursework in STS

Last fall in our graduate student seminar, we focused on STS orientations to the curriculum. We started by reading the literature on situated learning, worldviews, and different subcultures students function within (see articles list at: http://sce6938-01.fa00.fsu.edu/readings.html). While this literature offers a valuable starting base, we felt the perspectives represented needed to be transformed and elaborated on in order to be of most value in developing a framework for STS

and a philosophical praxis. Some discussions led to these further and possibly missing considerations:

- developing more sophisticated and contextualized thinking (see Lawrence & Lambert, 2000),
- considering how STS would work based on limitations to agency in some cultures or on their expanded possibilities due to a communal orientations not typically present in Western cultures,
- looking at subtle differences in perspectives, i.e., local difference such as farming or urban communities, not just obvious worldview differences such as Native American vs. Western science views, and
- considering the limitations of current situated learning perspectives (Hildebrand, 1999) as well as taking postmodern theoretical perspectives into practice.

The nature of science also surfaced as difficult or minimally understood. However, in addition to understanding science as a cultural endeavor, as tentative, and so forth, an expanded view of what counts as science helps bridge STS in practice with worldviews, subculture considerations, and practicing science as inquiry with a science for all perspective. Short articles such as VonTobel's, "Two ways of knowing" (1989), and, Shurin and colleagues, "In defense of ecology" (2000) are good for provoking thought.

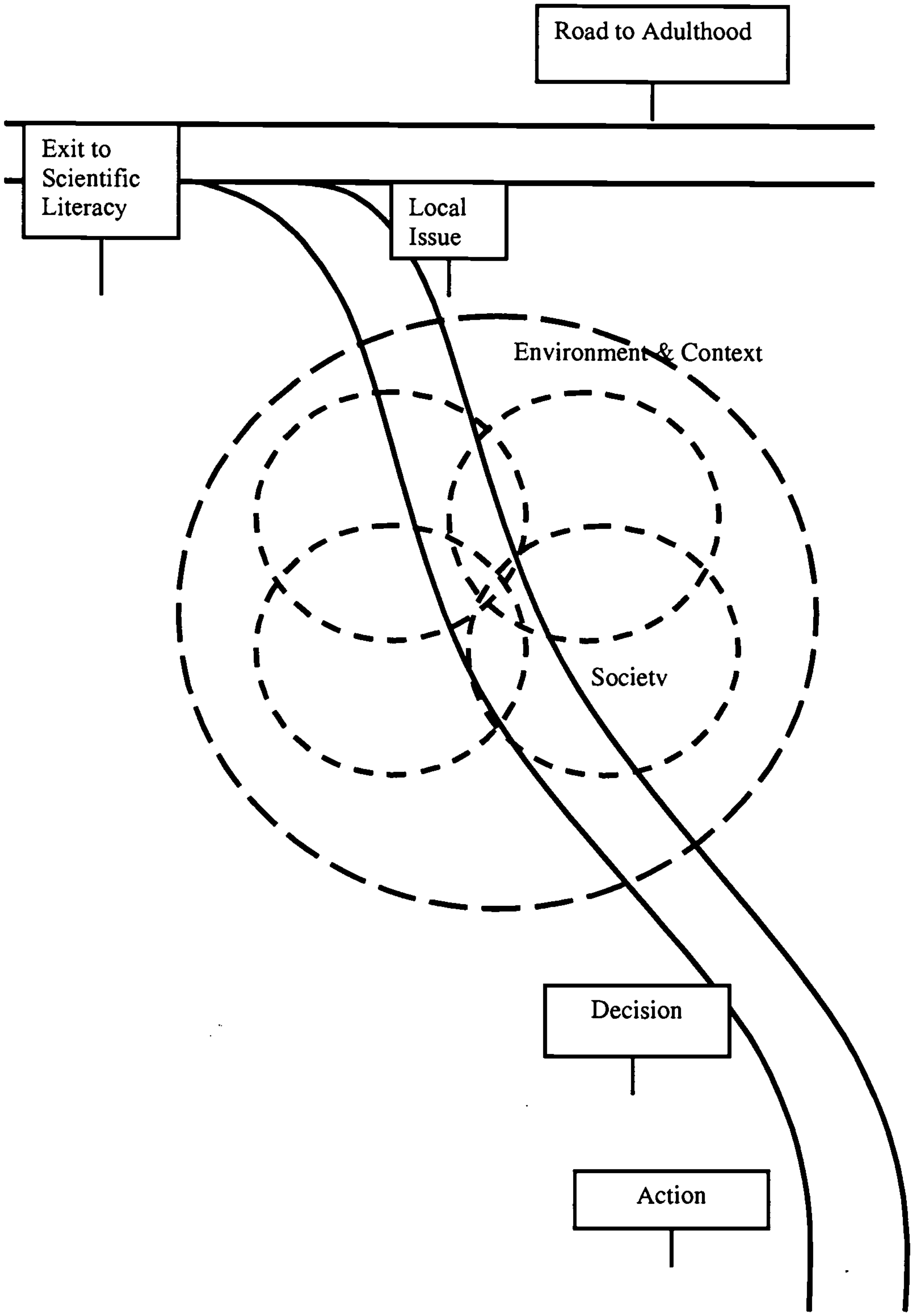
We had many interesting discussions focused on the nature of technology and its relationship to science and society, particularly on "What is technology", since everyone had a vision of technology as either computer technology or technical tools, but not an expanded vision which included technology as the human-made world, as design, nor as a social-cultural construct.

We considered what STS promotes that other perspectives, particularly in science education, do not promote. We talked about the critical aspects of an STS orientation...What makes it STS?, Why is an STS orientation important?, and, How do STS orientations help integrate other perspectives and account for student needs, interests, and diversity while still learning science on a deeper level? Nearly every course participant said their understandings of STS turned a corner when reading Harms and Yager's (1981) list of critical aspects of STS orientations - seeing STS as a more encompassing perspective of curriculum and the underlying philosophy. Looking at the purposes of schooling and a "science for all" perspective led us to considering holistic development, especially from early through late adolescence. What emerged through discussion was a complex web of understandings that includes:

- developing personal agency (see Wells, 1998),
- honoring culture and providing scaffolding from one subculture to another (see Aikenhead, 1996 & 1999; Cajas,, 2000; Ogawa; 2000), and
- seeing students as integral parts of their community instead of as being schooled (see Lemke, 1994; Lesko, 1996).

Understandings of STS have universal features as well as being very personal and necessarily unique to each context; the school, the community, and the students. Over the semester, students progressively developed more sophisticated guiding frameworks of STS orientations to integrate key ideas (see Diagram 1) and their own areas of interest in STS (see Sowell, 2000 & 2001). We were concerned about certain trends in the classroom. A survey by Hancock (2000) asking teachers in Miami what they thought about STS, revealed the typical response was superficial understandings and classroom application, albeit positive. STS is seen

Diagram 1: Example of STS Framework



as simply being the "little boxes in text books" was often mentioned. STS has become an add-on in many classrooms, but not an orientation to the curriculum that is rich in the philosophy of schooling and theoretical notions about teaching and learning. The STS boxes and life relevance is often something mentioned during a unit but not experienced by classroom students in science. This understanding of STS could be akin to the problem with 'hands-on' labels, i.e., students are actively doing something, but it does not mean they are conducting inquiry nor are they thoughtfully engaged. We pondered if the popularity and adoption of more inquiry and problem-based learning approaches would solve the relevance problem and discussed whether these approaches are actually STS in disguise or so closely related it makes no difference. Our thoughts were that many other orientations do not consider the deeper issues related to curriculum but in practice appear to closely mirror STS orientations. However, they may not mirror STS orientations as closely on a broader and more holistic level or when looking over the curriculum.

Some students characterized STS orientations to the curriculum as a concrete example of the postmodern curriculum theory they had considered in-depth in other courses although STS seems to have a much more pragmatist or neo-pragmatist orientation – an orientation that is curiously not emphasized as postmodern by many proclaimed postmodernists. At its foundation, STS is future and idea oriented, concerned with both the community and the individual, and represents praxis much more than pure idealizing. If anything, those promoting STS have not proclaimed nor elaborated its strong basis in both philosophy and theory as much as they should.

We ended the semester, somewhat out of time, with discussions about thinking and some current theory on developing reasoning, contextual thinking, epistemologies, and ill-defined disciplines and problems. For me, the past two semesters have been a journey of reflection on my

own teaching and research. I wondered if constructivism was enough to guide my teaching? While I still base my understandings of learning on basic constructivist assumptions, I spend more effort on developing situated experiences, community, and collaborations in my classroom and see 'ourselves' as a working group. I have given up the 'facilitator' role that always seemed inauthentic and passive for a role as a co-participant even though my role is as the leader or the group.

An Extended Community: Praxis and STS

Praxis in graduate courses necessarily means including 'practice' as an integral component – just as it would for a preservice teacher or a practicing teacher. While practice can refer to teaching in the classroom, it also has a larger meaning and includes those ideas we think of as professionalism - that of sharing and reflecting on one's practice through different means. I shared some of my burning concerns with graduate students and colleagues having tried integrating an STS perspective into science methods courses:

- Since these orientations involve much more student choice and self-direction, how can we help science teachers plan in flexibility and alternate paths into learning experiences?
- How can teachers learn to promote structure as a scaffold not a constraint on knowing and transition students into roles of greater agency and self-directedness over time?
- What kinds of qualities should teachers look to promote in students' thinking and how can these be promoted?

Often, I will share a concern in my teaching or just an idea with a graduate student because they offer a different point of view based on their unique experience. More importantly, because it engages them in the conversation of shared practice. It models being a reflective practitioner who

doesn't have all the answers, who is constantly growing, and who honors their understandings and abilities. It helps us to build more sophisticated understandings together.

At the base of STS is community; students as part of their local community, community members as part of learning, teachers as part of their local and professional community, and classroom communities. At the University level, praxis in science education also involves seeing your practice as part of these communities and in building community with faculty in other disciplines and with other science educators. Last fall, several of our colloquium speakers intersected with our discussion of STS orientations; presentations by two school principles involved in progressive and whole school reform, a video on the nature of science and worldviews (the classic, 'Mindwalk'), a GLOBE presentation by a meteorology professor, a presentation on the language represented in science and feminist perspectives by an oceanography professor, and a presentation by another oceanography professor who teaches an environmental issues course. These perspectives were thought provoking and allowed graduate students to see that others' ideas are not all traditional, that we are not just idealizing from the ivory tower. And they could see that the ultimate goal is to eventually intersect with other members of the community as part of a working group.

Fortunately, three of my graduate students from last semester Scott Sowell, Elizabeth Hancock, and Yalcin Yalaki accepted the invitation to be a part of our interactive session at AETS, three that have helped me enlarge my own thinking and reflect on my own teaching. Together we talked about what questions could serve as focal points at AETS. Although the following section focuses on our AETS session, many other interactions with colleagues occurred before and after to help challenge our thinking and develop our understandings.

Science/Technology/Society Orientations to the Curriculum

In opening our session at AETS, Bob Yager reminded us again that our primary focus is students, and we must honor and promote their curiosity about the world. All students have questions about their world, and science is about questioning and seeking that leads to developing investigations, evaluating the alternatives and evidence, and formulating new questions. We must be cognizant of how student curiosity is discouraged by much typical 'schooling'. Bob expressed his puzzlement at how anyone could be against STS as its basic definition is learning centered in the "context of the student as a person in a cultural/social environment (Harms & Yager, 1981)." Technology and science are never separated from our social world or world of work.

> Science is in use pervasively in our society. It is in use in the basement of the school building where the building engineer or custodian works with the heating system, the plumbing, the ventilation and air-conditioning, the electrical circuits that serve the building. It is in use behind the scenes at the museum in work on preservation and restoration, preparation of exhibits, and scientific research. It is in use at the local power plant, the local sewage treatment works, solid waste recycling center, transit system, auto repair shop, medical clinic, pharmacy, manufacturing plant, agricultural station. (Lemke, 1994, p. 1)

However, the deeper relevance of science and technology to even our daily lives and world of work is often elusive in the classroom as are developing students understandings. .

> ...our curricula must work to insure greater continuity in students' ways of experiencing as they move from one classroom to another and from classroom to hallway to neighborhood to home (Lemke, in press-c). There is no more reason to believe that the habits of vital experiencing will automatically transfer to the rest of students' lives than that habits of technical reasoning will do so. What lasts for the longterm in us is what we have learned how to remake for ourselves across many contexts. This is not only an argument for more multi-disciplinary curricula, but for the curriculum to work more vigorously against the radical separation of school from the rest of students' lives. It is a very Deweyan concern.

In our discussions both before AETS and with session participants, we wondered what it takes to understand curriculum in this broader sense and teach from an STS orientation. Understanding the 'ideal STS' or the underlying assumptions of STS orientations is important to consider as a starting goal, something to strive for. Deeper understandings are needed to promote such learning at the university level and so teachers know where they might go even if they are under some constraints either in their personal understanding or because of curricular and school limitations and cannot accomplish the ideal.

Understanding the ideal also includes having deeper understandings of such underlying aspects as developing student agency in a developmental sense (not just motivation to learn science), conceptualizing and planning a living, dynamic curriculum overtime as well as on a daily basis, deep understandings of the nature of science and technology, and the intricate interplay between science, technology, and society. Classroom teachers and those promoting STS orientations in university level courses need a deep understanding of the underlying philosophy. This understanding takes place overtime, through practice and reflection. Unlike many other orientations, like problem-based learning, which do not seem to have a philosophical base, deeper understandings of STS orientations may require "a commitment to human welfare and progress" and philosophical positions that influence "all aspects of curriculum and teaching practices (Harms & Yager, 1981)

Group Discussion

Ideas about critical thinking and scientific reasoning skills surfaced repeatedly during our discussion and were agreed upon as important. However, such catch phrases can often mean different things to different people and are seldom attached to specific classroom practices. Herbert Their contributed the terminology "evidence based analysis" to sum up those catch

phrases and to emphasize the skill of *analyzing* information using *evidence* that has been gathered and interpreted by the students themselves during STS units.

STS allows students to discover and interpret interrelationships within the natural world. This can be contrasted to a more traditional science classroom where science is distributed piece by piece, unconnected to the real world of the student. Since STS can establish a connection with the students' own lives, it is more likely that the goal of scientific literacy can be accomplished. Students will more readily incorporate science into their lives if it is presented in a manner comparable to their own personal subcultures.

An action component can often be the culminating activity for an STS unit. This activity stems from the students' growing expertise and agency about the issue being studied. However, it is important that the students remain the foci for the entire period. They should be in charge of how they take action with the science knowledge that they have established. It should remain personal and purposeful to them throughout the entire process.

By no means is an STS orientation to the curriculum an easy feat; it requires rigorous and authentic scientific work. It places a much higher responsibility on the teacher and the student. However, the benefits are in line with current science education reforms.

Teachers must create a unique classroom community in order facilitate an optimal STS experience. Students, as mentioned before, should be the foci of the entire unit of study. Their classroom should be a safe environment where they feel comfortable taking risks and asking questions. It should be a "personal classroom" where collaboration and communication are valued commodities. As one member of our group put it, you would like to hear "my brain hurts" kinds of conversations going on between students. We felt that students should be expected to support their opinions during discussion, and that through this type of discourse, new

connections could be made for the entire class. Research into dialogue and discourse (Wells, 1998) could enrich our understanding by being incorporated into this developing theoretical framework of STS.

Students should feel that they are a part of an important, learning community; one that is actively involved in something meaningful, purposeful and relevant. They should be able to feel the connection with the local community outside of the school walls. That is where they live and that is where their scientific literacy will eventually be expressed. The more human interaction with each other and with the outside community, the more the science feels real and useful. STS has the ability to take independent, fragile knowledge and cradle it within a valuable, living context.

The definition of the word "curriculum" also surfaced during our conversation about STS. If STS is to broaden our way of thinking/teaching/learning science into a more humanistic and holistic manner, so should our view of curriculum. Instead of a list of facts that should be covered, the term "curriculum" should also be holistic, including the relationships between teachers and students (and between students and students) and how these relationships affect the learning within the classroom.

Being innately interdisciplinary is one of STS's greatest strength. It is seldom that science or scientific thinking exists in isolation in the real world. So why should it be taught in isolation in the classroom? Since STS involves students in authentic scientific issues, it draws clear connections to math, language arts, social studies, performing arts, computers, etc.

Some teachers are reticent to try STS in their classrooms. The inner life of the teacher and their reflective journey overtime is of the greatest importance. It is a journey that is simultaneously individual, social and collegial; a journey much more difficult than just

understanding inquiry or being able to transform science into exciting learning experiences. We believe that to more fully understand STS orientations, how they are promoted in different contexts, and to develop the foci of research, we will need more science educators at all levels able to engage in praxis

Interior Activities: What Must A Teacher Consider When Adopting an STS Orientation?

Working from an understanding that STS teachers act as individuals in unique contexts, teacher educators seeking the adoption of an STS orientation among their students must consider the following question: What must a teacher consider when adopting an STS orientation?

The few teacher accounts (McLaren, Yorks, Yukish, Ditty, Rubba, & Wiesenmayer, 1994; Jeffyres, 1998) that exist form the beginnings of an image of what teachers must consider and do in order to implement STS: laying out broad questions, establishing a flexible framework for learning experiences, and giving students agency and voice in the evolution of those learning experiences.

Research that focuses on the work of STS teachers (McGinnis & Simmons, 1999; Mitchener & Anderson, 1989; Pedretti, 1996) reveals many important issues. The pressure to cover content, whether it is perceived or real, presents a serious limitation to STS implementation. A teacher's understanding of her students, the school context, and the community norms is vital to creation of successful STS education. STS teachers must work from a carefully considered, personal vision of their work and STS.

The suggestions made by researchers and theorists in STS education (Ajeyalemi, 1993; Bybee, 1991; Rubba, 1991; Waks, 1992; Williams, 1994) focus on the interior activities and dialectical relations of STS teachers. The interior activities of STS teachers should include establishing one's own theoretical position on science and teaching, planning for instruction, and

attending to the role of students in the learning experience. STS teachers maintain a dialectic with resources, other teachers, and students.

In summary, when developing theoretical positions STS teachers must consider the role of students in the planning process and learning experiences; insure their understanding of the students, the school context, and the community norms; develop a flexible framework for learning and establish broad questions to guide the learning.

There are other considerations for STS teachers that have not been explored in the literature described above. Viewing classrooms as sites of culture creation (Aikenhead, 1996; Levinson & Holland, 1996) has important implications for STS education. STS teachers must consider their own beliefs and values related to societal issues and the impact those beliefs and values have on the act of teaching.

Group Discussion

Our group addressed the question: What must a teacher consider when adopting an STS orientation? And, to clarify the following elements of this issue: teacher beliefs/theoretical framework, contexts, student role, and planning/organization. We focused our conversation on consideration of the categories that emerged in the literature introduced above: beliefs and theoretical frames, planning and organization, student agency, interacting contexts, and experiences.

Within the realm of beliefs and theoretical frames, a teacher adopting an STS orientation must articulate her notions of epistemology and pedagogy with particular attention to the cognitive abilities and learning styles of her students. The teacher must address the nature of science with a particular focus on inquiry, the relationship between science and culture, and non-Western notions of science. Since the ideal implementation of STS includes social action,

teachers must consider their position on political, social and ethical issues and the relationship of these issues to science.

The development of beliefs and theoretical frames is intimately linked to the experiences of the teacher prior to his entry in a teacher education program, as a pre-service teacher, and as an in-service teacher. We believe it is vital that teachers experience STS as students in their own science coursework. Achieving this demands the thoughtful involvement of science faculty. The literature on teachers involved in STS instruction does not introduce experiences such as risk taking, participation in social action, involvement with politics, and tackling of controversial issues. We feel that these experiences may be vital to an STS teacher's exploration of social issues and pursuit of social action.

When considering preparations for STS instruction, the teacher will need to develop a flexible framework that balances student agency and professional obligations. The teacher will also need to consider the balance among the science, technology, and social elements of an STS orientation. High quality STS preparations will almost certainly involve dialectic interactions with other content teachers and members of the communities within which the school is situated.

These communities are part of the interacting contexts that an STS teacher must develop an awareness of and consider student engagement with. These contexts include the school, science, society, and the community. Beyond the school and local contexts are regional contexts that influence and are influenced by the local issues pursued by students. AN STS teacher must also recognize that these interacting contexts have unique cultures and that students bring their own worldview to their interactions with these cultures. Learning experiences that move among these interacting contexts are limited by the institutional structures of schools and school systems. This is particularly evident in concerns over accountability and covering content.

Considerations related directly to student agency did not emerge in our conversation. During our conversation it was suggested that experience is a key in facilitating teacher adoption of an STS orientation. It was also suggested that the notion of interacting contexts is unique to STS and should be a key focal point in educating science teachers.

Much research is needed on how we can help beginning teachers, either already in the classroom or in preservice science education programs, transition towards STS orientations. Understanding how to develop inquiry lessons, question students, promote collaborative learning, and so forth maybe a start, but does not constitute an STS orientation. Typical science education methods courses do not help preservice science teachers understand how to develop integrated and extended units in the classroom or think about holistic student development and curriculum on a broader level. It is even more difficult to give preservice science teachers experiences in teaching something more than "by the lesson plan" prior to entering teaching. Some programs, such as the Iowa based Scope, Sequence, and Coordination program have provided excellent professional development models to scaffold practicing teachers in learning STS orientations and directly apply what they have learned in their own classrooms. We need more of such programs so that practicing teachers can work in conjunction with science education faculty to help scaffold preservice and new science teachers, provide a collaborative and supportive community, and supply teachers who can be powerful spokespeople in their districts and in science education professional research and teaching communities. There is much we do not know about how new science teachers come to understand and implement STS orientations particularly given that they all enter at different place, with different understandings, and will teach in diverse contexts.

Transitioning: How do Teachers Make Transitions to STS Teaching?

Science teaching is a spectrum of approaches that extends from traditional to STS. We believe traditional ways of teaching and teaching from an STS perspective are the two extremes of this spectrum. A few of the most striking differences between these extremes identified by Hurd (1981) are presented in Table 1.

Table 1: Traditional vs. STS Orientations

Traditional Orientations	STS Orientations
Teachers and textbooks are the main sources of knowledge	Students actively seek information to use
Science is abstract and has no relation to technology or daily life	Students see science as a way of dealing with problems in everyday life
Students concentrate on problems that are identified by the teacher or textbooks	Students identify problems about themselves or their community and take responsibility to solve those problems by using science
Minimal consideration given to human adaptive capacities	Human adaptation and alternative futures emphasized
Value-free interpretation of discipline bound problems	Value, ethical, and moral dimensions of problems and issues considered
Curriculum is textbook centered, inflexible; only scientific valid is considered (and from a limited view of content)	Curriculum is problem centered, flexible and culturally as well as scientifically valid
Information is in the context of the logic and structure of the discipline	Information is in the context of the student as a person in a cultural/social environment

The list for these differences is much longer of course. It is clear that for a teacher who uses a traditional approach in his/her teaching or for a pre-service teacher who received a

traditional education throughout her life, it is not easy to shift to an STS approach in a short time. Many teachers may integrate some facets of STS in their teaching or incorporate inquiry as an important experience, however, they also face a transition into STS teaching. In other words, each pre-service or in-service teacher brings different understandings and starts from different points of entry. There should be a time period in which the teachers take conscious and cautious steps toward an STS approach, if they see any value to it (Figure 2).

The questions are, "How should those steps be taken?" And, "How can we find different avenues into developing further understandings of STS orientations and implementing it in classroom practice?" Given an ideal situation, "What is the nature of these avenues?" What process or major steps have others in this group gone through or helped pre-service/in-service teachers go through? What are important considerations in helping to promote this change?

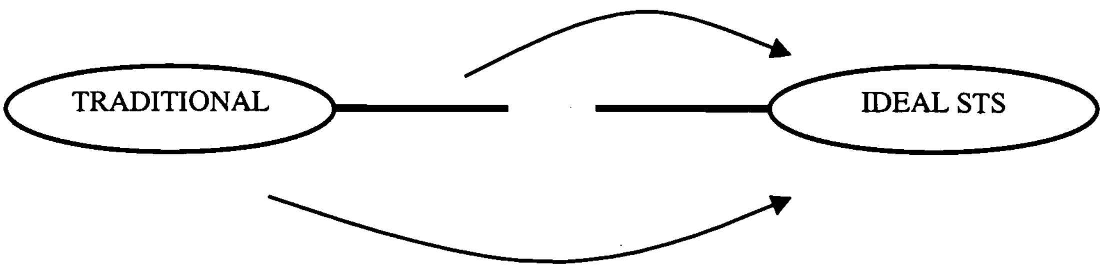


Figure 2: Transitioning Toward STS Orientations: Pathways

Instructional techniques for STS education include developing simulations, cooperative and collaborative approaches, inquiry based learning, independent projects, small group discussions, case studies, surveys, oral presentations and written reports. However, teachers

should understand that STS is not only about applying some of these approaches. STS is more about, as May (1992) puts it,

> ...promoting an ecological, moral, cultural, pluralistic, and spiritual perspective, an "ethic of caring," and a critical pragmatism based on contingencies that make our decisions and tasks all the more complex but necessary if we are to create a better world for ourselves. (p. 81)

Science teachers are the most important (but not only) key in shifting toward STS education. Therefore, for a successful shift to occur, science teachers has to have a very complete understanding of what STS education is about and the philosophy behind it. They also need support and help from other people who involved in education. According to Heath (1992),

> Many good STS units and programs result from individual teachers striking out on their own filled with enthusiasm, ability, and dedication to the importance of STS, but with little support. Without support, it is difficult to expend or maintain the quality of ongoing STS instruction. Technology, interdisciplinary teacher teams, partnership with universities could be sources for support. (p. 52)

Rubba (1991) suggests that, STS has not attained the level of implementation recommended by NSTA because the majority of the science teachers are not prepared to teach STS. Before STS teaching practices can be fully developed and put into practice appropriately, science teachers' beliefs and values about science education must be restructured in such way that, they can fully appreciate what the notion of responsible citizen action on STS issues as a goal of a school science education.

In the literature there are suggestions about the transition toward an STS orientation. For example Rubba (1991) suggests a project approach, which refers to STS issue investigation and action instruction, as one model of STS instruction. This approach consists of 4-6 week units that can be made part of a science course.

Heath (1992) suggests that most common approach to STS instruction appears to be infusing STS themes into science or social studies courses at the middle or high school level. This is done by developing new units, modifying or extending existing units with new materials and activities. Developing new STS courses is another approach for STS instruction.

Pedretti (1996) also suggest that infusing STS material, modules or units into existing courses is a more supported way of initiating STS education into school curriculum than developing separate STS courses.

Group Discussion

One of the main ideas that came out in our group discussion was that a transition toward STS education takes time and requires determination. Students need to be prepared for STS education and for the kind of assessment that is going to be used. The control over students' learning should be slowly shifted to the students themselves. Instead of answering every question that students ask, new questions should be asked of them in order to make them think and come up with their own answers and make their own decisions.

Another main idea was that short time experiences might be useful during the transition toward STS education. For example, open-ended STS activities, embedded into science curriculum as STS units, could be the context of these short time experiences. After such STS activities a discussion with students about the activity, talking about what worked well and what didn't, analyzing the roles of students and teachers in these STS activities may help to improve future activities. If there are enough resources, STS courses can be designed after experimental short time experiences with STS activities in science classes. Bob Yager suggested that:

> One of the best ways for teachers to move to STS teaching is to involve them in a discussion about some current issue - one currently in the news. This situation can lead to questions, to needs for interaction, to interactions with experts from written word or in person. All of this leads to interactions that can be used in

> dealing with the issues. Many teachers can be involved with such activities and conversations - and then think about doing it with students. Teachers need to identify what they did. What they learned, and how they used their learning. Then the question can be posed. What prevents you from trying such an approach with your students - for one class period or a month? Then analyze what happened with the students. Let them propose how to develop even bigger and more complicated issues to consider.
>
> Many new STS teachers can tell of stories about how their students reacted. Many can provide evidence of what their students did and how they learned to resolve such issues. They often become 'experts' and enjoy their 'knowing' and the use of it. This is central to an STS investigation. It's an odd situation, both teachers and students often forget what they have learned as they are engaged with the issue.

One of the other issues that we talked about in our discussion group was the availability of support to the teachers who want to implement STS education. Administrative and parental support is important in implementing STS into the science curriculum. If administrations in schools and parents become familiar with STS education and its potentials, they may be more willing to support STS education and the teachers who are trying to implement it. Student presentations to demonstrate their accomplishments in STS activities may be helpful to familiarize administrators and parents with STS education.

In brief, the main points that came out from our discussion were that, any transition to STS education is not a simple process. It requires patience, determination, time and good planning. It is important to inform students about what STS is and how the instruction will change with STS. Teachers need to proceed toward STS education step by step experimenting with short STS activities and use these experiences for developing more comprehensive STS units. Teachers also need to get support from school administrations and parents. They can do so by providing information about STS education and trying to explain the advantages of STS to administrations and parents.

Implications and Future Directions

STS, Culture and Community

Our discussions highlighted a number of considerations, which we would like to probe more deeply. Aikenhead (1996) describes learning science as culture acquisition, where culture includes concepts of norms, values, beliefs, expectations, communication, social structures, customs, worldviews, and technology. He advocates an approach to science education that assists students in making smooth crossings of the borders of their culture, society, science, technology, and the culture of school. Levinson and Holland (1996) describe culture as continually being created and changed. Classrooms have cultures of their own, which are being created by the teacher and students. Given this, it may be more appropriate to see science education through an STS perspective as the creation of a culture and a community. The students and teacher create the norms, expectations, communication, and boundaries together. From this perspective, a teacher must consider the kind of culture she would like to create, how she will create it, and what role the students play in the creation of that culture.

Previous research in science education has encouraged teachers to consider their students' sociocultural worlds to enhance the quality of classroom instruction. (Aikenhead, 1996; Aikenhead & Jegede, 1999; Brown et al, 1989; Cobern, 1996; Costa, 1995; Hawkins & Pea, 1987; Waldrip & Taylor, 1999)

Cobern (1996) cites worldview when addressing the current reform measures on scientific literacy:

> ...all the definitions of scientific literacy include the embrace and application of science in everyday life – but one will apply science only when it fits one's sense of self and environment, personal goals, and understanding of how the world *really* is – in short, if one has a scientifically compatible worldview. (p.586)

Teaching from an STS perspective in a school context is a complex task. In order to facilitate more widespread implementation of fully realized STS education; teachers, educators, scientists, and researchers must collaboratively address the following questions:

- What is the relationship between contexts and implementation of STS?
- What role can teachers play in mediating contexts unfriendly to STS?
- What support exists within the science community for STS education?
- What STS science experiences are appropriate for teachers intending to implement STS in their own work?
- What are the experiences of STS teachers?
- What are the implications of the classroom-as-site-of-cultural-creation perspective?
- How do STS teachers deal with the relationship between their personal beliefs and their teaching?
- What does student agency look like?

We end our discussion with an appropriate quote from *Blueprints for Reform* for *Project 2061* (AAAS , 1997) on recognizing the power and importance of using teachers for curriculum reform and their intimate involvement in any successful and shared praxis:

> The most effective curriculum connections are designed at the school by people directly involved with the school: stamped-out curricula tied to written-to-formula textbooks have served teachers and students notoriously poorly in the past. Even if we disregard the growing sentiment that teachers and administrators must be given the freedom to design instruction relevant to their students, the resistance of many teachers to top-down mandates implies that those implementing science education reform must drive its local design and application.

STS and Social Advocacy: Citical Issues (by Paul Jablon)

After 31 years of classroom teaching and working with prospective science teachers in the university environment the following is clear to my science education colleagues. Most people who have decided to become science teachers envision themselves simply engaging adolescents in the "wonders of science" that they themselves are so enamored with and soon find that for a majority of their students the beauty and discovery of science is not as compelling. This is true even for those teachers who engage their students in daily inquiry-based, hands-on, minds-on investigations. The same format for science education that worked so well with elementary students no longer has the same level of success with adolescents.

When presented with the possibilities of engaging their students in knowing science through the avenue of technology and societal issues a small percentage of the science teachers cautiously examine these STS materials. Of those that piloted this approach only a small percentage continue to use this approach as the focus for their teaching, despite their realization that many students previously disengaged become very motivated to learn science to respond to ethical societal decision making, mostly related to the utilization of technology.

It has been my experience that the ones most engaged in the use of the STS materials, and who use them most effectively with their students, were previously involved in social advocacy activities outside of teaching. These social advocacy issues were not necessarily science related, such as environmental or medical ethics, but many times dealt with poverty, racism and other social justice issues. This only makes sense as much of STS-oriented curricula are based in making social science and philosophical evaluations. Not only does it mean being comfortable with the format of this decision making, but also comfortable in leading groups of individuals from diverse backgrounds in making their own evidence-based decisions.

This leads to the need for both inservice and preservice orientation of science teachers in the facilitation skills and understanding of the ethical and philosophical frameworks in which this social science decision making occurs. Otherwise it is not fair to expect science teachers to embrace STS teaching regardless of its proven effectiveness.

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Interior Activities
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Transitioning
Group Leader: Yalcin Yalaki, Contributors: Bob Yager, Val Olness, Bill Robertson, Deb Waggett, Gado Issaon, and A. C. Banerji

EIGHTH-GRADE AFRICAN AMERICAN STUDENTS' SENSE-MAKING OF ELECTRICITY

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Culturalism emphasizes how the knowledge, experience and understanding that students bring into the classroom are direct outcomes of what has been instilled in them. Therefore, inherent to culturalism is meaning making. Meaning making involves situating encounters with the world in the appropriate cultural contexts. Culture assigns meanings to things in different settings on particular occasions. Although meanings are in the mind, the meanings have their origins and their significance in the culture in which they are created (Bruner, 1996).

The notion of culture, as related to science, concerns language, attitudes, beliefs, and values that predicate how people act, judge, and solve problems (Atwater, 1996), but social and cultural factors influence science (Lederman & Abd-el-Kalid, 1998). Children have views about a variety of topics in science from a young age and prior to formal learning of science (Driver, Guesne, & Tiberghien, 1985; Osborne and Freyberg, 1985; Wittrock, 1985). Students are able to make sense of the world in their own way based on their own experiences (Gay, 1995). According to Stepans (1995), the social process of learning creates an environment that encourages students to share, to explain, to negotiate and to evaluate.

Science literacy, inquiry, application, and critical thinking are key components of science education (American Association for the Advancement of Science, 1989; National Research Council, 1996). Students need to address questions such as: What is the evidence? How do we know? Why do we believe? How do we find out? Teachers should (a) accommodate various learning styles, (b) use students' ideas as a basis for instruction, (c) emphasize mastery instead of coverage, (d) emphasize understanding, making connections, and applying knowledge, (e) encourage a questioning environment, and (f) create an environment of contradictions and

inconsistencies in order to challenge preconceptions and motivate learning (NRC, 1996). Curricular and instructional design that changes students' alternative or intuitive conceptions about natural phenomena and promotes their ability to apply their knowledge in novel, problem-solving situations is an important issue in science education (Heller, 1992).

Purpose of the Study

The purpose of this study is to investigate the conceptions African American students have about electricity. Science education, based on conceptual change theory (Posner, Strike, Hewson, & Gertzog, 1982; Stepans, 1995), requires assessments of what knowledge students bring to instruction (Ausubel, Novak, & Hansesian, 1978; Heller & Finley 1992; Osborne & Freiberg, 1985). However, there is little research that supports conceptions African American children bring into the science classroom (Atwater, 1995).

Science education can no longer ignore the experiences brought to the science classroom by others. What scientific knowledge and skills do African American students use in their daily lives? How is this knowledge associated with what the students have already been exposed to in previous school experiences? Does classroom instruction embrace cultural diversity of students by means of culturally relevant pedagogy (Ladson-Billings, 1995)? How do implicit cultural assumptions, frames of reference, perspectives, and biases within a discipline influence the ways in which others culturally construct knowledge? The goal of this study is to identify and evaluate the sense-making African American students bring into a science-learning situation from a cultural perspective as well as to suggest how this knowledge informs culturally relevant science pedagogy. However, the authors acknowledge the assertion that "students, even those in different countries, may have the same idea, or the same interpretations of similar events" (Driver, Guesne, and Tiberghien, 1985, p. 3).

Multicultural science education utilizes constructs, methodology and processes aimed at providing equitable opportunities for all students to learn (Atwater, 1993). Banks (1993) has

identified five dimensions which conceptualize the essence and purpose of multicultural education: (a) content integration which allows teachers to use examples and content from a variety of cultures to depict concepts; (b) the knowledge construction process which advocates meaning making; (c) prejudice reduction which relates to the racial attitudes of students and the strategies teachers use to erase negative attitudes; (d) an equity pedagogy where teachers modify teaching such that education facilitates academic achievement amongst students from diverse ethnic, cultural, and gender groups; and (e) empowering a school and social culture which conceptualizes school as a social system that must be restructured with respect to curriculum, staff development, textbooks, and an assessment program in order to implement school reform with a diversity agenda. Cushier & McClelland (1992) indicate academic achievement amongst students of color and low-income students can be increased when teaching strategies and activities build upon the cultural and linguistic strengths of students, and when teachers have cultural competency in the cultures of their students.

Atwater (1998) stipulates that science will change, as the scientific community becomes more diverse. For this change to occur, society must embrace a multicultural context for science education. In order to increase participation of others in science education and to facilitate a science education of multicultural context, this study examines the prior knowledge of African American students. The knowledge African American students build depends on sense-making that they bring into the study of science (von Glasersfeld, 1995).

A multicultural education and constructivist framework focuses upon the learner's sense-making and connections to other concepts. However, teachers bridge the gap between learners and the real world by integrating subject knowledge and the ways of knowing (Philips, 1985). Thus, what the learner knows is important to what the student *will* learn. Bentley, Ebert, & Ebert (1999), Carr (1996), and Stepans (1995) identify interviewing as a vehicle to determine and to distinguish what the learner knows or does not know and what the learner understands.

Interviewing helps teachers understand students' conceptual development. In order to effectively intervene, teachers must formulate questions that elicit children's explanations as well as develop their ability to ask meaningful follow-up questions to determine why students are saying what they say.

Research Question

Driver, Guesne, and Tiberghien (1985) and Osborne and Freyberg (1985) support the premise that children have and do develop concepts alternative to those taught in schools and suggest that the investigation of children's sense-making will aid student learning. Thus, the research questions for this study are: How do eighth-grade African American students make sense of electricity? How do African American students construct cultural understanding about electricity? Are the African American students understandings concerning electricity culturally bound and if so, what are the cultural factors?

Methodology

Participants

The participants in this study were five eighth grade African American students from an urban, midwestern city. There were two male students and three female students. The participants were a convenient sample (Patton, 1980). Students, whose parents attended the district scheduled open house at the beginning of the year, were the participants. The first author described the nature of the research to the parents. The parents were asked to sign a district approved release form.

The eighth grade African American participants were given letters which described the purpose of the study and the methodology. In addition, the participants were given an assurance of anonymity. Therefore, the participants were assigned pseudonyms.

Description of Participants

Carl is an African American male who is small in stature. Because he initiates practical

jokes at the expense of others he is often described as an unpopular student with a seemingly immature personality. He might also be described as a somewhat bitter child.

Sarah, an African American female, is considered a quiet and introverted student. She rarely participates in class. "Nice and sweet" are words her peers use to describe her.

Pamela is a very outspoken, confident African American female. She is considered a student leader. Her peers consider her an academic over achiever.

Cathy is labeled a "trouble maker." However, she is an African American female honor roll student. She is very outspoken, has difficulty listening to authoritative figures and is often insubordinate with teachers and her unit principal. Seemingly Cathy gets into trouble on a regular basis in order to hide her intelligence.

Ronald, an African American male, is very talkative, athletic and popular. He is considered to be one of the most talented students in the school. In addition to being a strong B student, Ronald is a member of the school choir, track and basketball teams and the peer advising organizations.

Interviews

The first author, the participants' teacher, conducted the interviews. The science content in this study derives from the districts course of study. The participants had not yet received eighth grade instruction in electricity when the study was conducted.

The semi-structured interview about electricity was from Targeting students' science misconceptions: Physical science concepts using the conceptual change model (Stepans 1996, p. 123-127). A circuit board, batteries, wires, light bulbs, paper, and pencils were available during the interview. Circuit prediction sheets were also used (Stepans, 1996, p. 125 & 128). During the interviews, participants were asked to draw pictorial representations. Additionally, participants were asked to describe predictions made on the circuit prediction sheets.

The interviews were audio taped and videotaped. The audio tapes were transcribed. The

transcriptions were read and reread in order to discover themes, patterns, and topics (Lincoln & Guba, 1985). As themes, patterns, and topics emerged, the interview transcripts were annotated. Also, in order to enrich the sense-making description, the authors viewed the videotapes.

Interview artifacts such as drawings, interview transcriptions and video tape recordings allowed for triangulation of data. Triangulation involves the use of multiple data collection strategies, and data sources (Gay, 1996). Internal validity was sought by the process of triangulation or inferring or finding evidence from one type of data in additional and different sources (White, 1985).

Findings

Carl's Story

Carl initially seemed nervous, but he swiftly became more comfortable with the interview. For Carl, electricity was " an energy source." Likewise, batteries "power up other objects." Carl stated, "Electricity is necessary to see and get work done."

Carl defined a circuit as "an object that carries electricity from one place to another." A light switch was an example of a circuit. After identifying batteries, light bulbs, and wires, Carl made a drawing to demonstrating how he could make a bulb light. In his drawing, Carl labeled the battery, wire and the light bulb; however, he did not indicate the flow of electricity or positive and negative terminals on the battery.

Next, Carl took the batteries, light bulbs and wires to make one bulb light. Carl immediately surveyed the objects and began to work. Using both black and red wires, and a light bulb, Carl was successful and seemingly unchallenged by the hands-on task. Also, Carl was able to describe how he made the light illuminate. He stated " [I] connected the circuits to the battery and the other end of the circuit to the light bulb to transfer energy to the light bulb....the red one is negative and the black one is positive."

Carl studied Prediction Sheet 1. He turned the sheet in several directions, Carl predicted

that picture Number Nine would light because "it's carrying energy from the negative end to the positive end."

For the two light bulbs task, Carl immediately began drawing. Within the drawing, Carl labeled the batteries, wires, bulbs and indicated the color of the wires. He explained his drawing. "The three circuits are connecting the battery with both of the bulbs so energy is coming from the batteries to both of the bulbs."

Carl also successfully lit the two bulbs. Carl explained. "I connected the two, four circuits together so they would bring energy from one circuit to the light bulb and the circuit took energy from that one to the other light bulb." Carl was asked "what would happen if you unscrewed one of the light bulbs?" "The other one would get brighter," he responded "cause it's more energy going into the battery now that the other doesn't need to be powered."

With reference to Prediction Sheet 2, Carl indicted Number Four would light. Carl stated '[because] the energy is flowing from one side of the battery and the circuit is taking it back to the negative end… so there is energy coming from both sides of the battery to supply the light....the more energy that has to be supplied the less that's going to be supplied to one like it. I can't explain the more bulbs you have the less energy that's going to be in each bulb because it has to supply energy for all the bulbs and not just one."

Sarah's Story

Sarah was visibly nervous. The interview was restarted several times due to her uneasiness. For Sarah, "electricity is like how things run and how things work....we use electricity by turning on the TV and… um using light and… um cooking." On the other hand, Sarah stated batteries "run...how things work."

Sara identified " a battery, a light bulb, wires." when asked to define a circuit, Sarah replied "un ah." When ask to draw a picture to make the bulb light, Sarah stated with uncertainty in her voice, "Wouldn't you need a plug or outlet?...a light bulb with a plug." Sarah pointed to

number one and said "this one....because you have to have the wire up to the metal part to make it work" when presented with Prediction Sheet 1. She made several attempts to assemble the wires, light bulb and battery together but was unsuccessful. Sarah replied "it's not lighting, I still can't get it to light."

When asked to draw a picture of two bulbs that would light, Sarah refused. Sarah also refused to assemble two bulbs.

Pamela's Story

Pamela stated "batteries help energize and charge objects without plugging them into a wall." Likewise, "electricity is… things to charge and help reenergize things." Pamela commented that electricity exists in "our daily lives...in cars, houses, and radios....In houses we use them to plug into walls like appliances, and in cars for radios. For radios we use them to listen to music." Also, Pamela defined a circuit as something that reenergizes and charges things.

After drawing a picture of a light bulb that would light, Pamela indicated " a negative side, the positive side, the wire, and the bulb." Pamela predicted Number Six on Prediction Sheet 1 would light "because here is the battery, it comes from the negative side into the bulb and the light bulb lights." Next Pamela tried several ways to make the light bulb illuminate. She became frustrated and stated "it won't light." However, Pamela continued to try to make the light bulb light for several minutes and just finally gave in with a big sigh.

Next, Pamela drew a picture of two light bulbs that would light. She described the drawing as "the negative side will go over to this bulb. It will have to have wire right here connected to the bulb." On Prediction Sheet 2, Pamela selected Number Two and stated "it has the negative, the positive and it has two wires coming up to the socket." Lastly, after some encouragement, Pamela refused to build the two bulb model. She blurted "Nope it won't work." Pamela already felt defeated and was not going to struggle to make two bulbs work as she did with just one. Pamela stated, "it takes a lot of studying [to understand electricity], to know how

to hook up batteries and circuits to make them light."

Cathy's Story

With a high level of anxiety, Cathy stated batteries "make things work." She defined electricity as "it's like lights, telephone, anything you got to plug in you use electricity." Also, Cathy stated "turning on lights and listening to the radio were ways we use electricity in our daily lives."

After correctly identifying a battery, light bulb and wires, Cathy stated that a circuit is "the things that are in the basement and you gotta, like if the lights go out or something you gotta push the button in to make them come back on." Cathy drew a circuit breaker box when asked to draw a circuit. Cathy explained "these would be upstairs lights and some of these would be downstairs lights. Like if the light upstairs goes out in say, the living room would be this one, you push this button. It will say "on" on one side and "off" on the other. If the thing is turned on."

After Cathy finished drawing a picture of a light bulb that would light, she explained "one side is positive, the other side is negative, you put a wire on the negative side and a wire on the positive side and hook it to the light bulb and it will light up." Using the materials in front of her, Cathy immediately assembled the materials. She successfully lit the bulb. On Prediction Sheet 1, Cathy chose Number Nine. She explained "because it has the thing coming from the bottom and the light bulb's on the positive side."

When asked to draw two light bulbs that would light, Cathy did so easily. She predicted that Number 4 would light on Prediction Sheet 2. However, Cathy had difficulty making two light bulbs light and stated that " it can't be possible it ain't enough wires." Cathy predicted that if one light bulb was unscrewed, the other light bulb would not light. Also, as a final statement, Cathy stated " it [electricity] is a power source."

Ronald's Story

Ronald stated "they [batteries] activate things," appearing to be cool. In order to define electricity, Ronald responded "I guess you could say lightening." Also, Ronald stated "using electricity, like using your stove."

After identifying the "D batteries, 1.5 volt battery, light bulb, wires" and asked to define a circuit, Ronald responded " I know what [a circuit] is but I can't explain it" Ronald draw a circuit. He explained "this is a light switch, you have these wires connected. I did not put in a battery. There's a battery and another wire connected to the battery at the positive and negative side, and there are two or three other wires."

When asked to draw one of the light bulb pictures, Ronald began immediately. He explained "you have to have a wire here, this is the tip, another wire, and your battery. That top of the wire touches that and that one touches this....this is the light bulb the bottom part right here already is connected to the wire and the wire is connected to the bottom of it to the positive and the negative side of the battery."

When asked to make one light bulb light, Ronald made several attempts and questioned if the batteries worked. Ronald kept trying with a look of disbelief on his face about the batteries working. When asked if he felt he had enough materials, Ronald said in a frustrated manner, "No!"

When asked if he could make a drawing of two light bulbs, Ronald did. He was unable to make the two bulbs light because he felt the batteries were dead. Opon departing, Ronald uttered "electricity is needed for almost everything. You need batteries when you don't have electricity."

Conclusion

African American students make sense about electricity by believing that electricity comes from plugging things into an outlet. The students in this study likewise cited using the telephone, turning on lights and playing the radio as examples of "what electricity is." Bruner (1996) stipulates that interpretations of meaning reflect not only the idiosyncratic histories of

individuals, but also the canonical ways of constructing reality. If the student's reality of concepts related to electricity is turning on the TV, lights and listening to the radio, then teachers, curriculum developers, science educators, etc. must begin instruction at this stage.

Culturally, African American students are visual learners (Hale-Benson, 1990). Therefore, examples and analogies of abstract concepts must be visual, concrete and relevant to African American students' own world. The students described electricity as an object being plugged in. This notion was evident in Sarah's, Pamela's and Cathy's story. They related electricity through their own experiences with turning on the TV, listening to the radio or cooking. However, Sarah selected a correct light bulb configuration. Cathy made the bulb light. Sarah, Cathy and Ronald, had no prior knowledge concerning the source of electricity other than their experience with plugging in a radio, or using the telephone. Although Carl and Pamela indicated that electricity was an energy source, only Carl could make the bulb light. Although these students' experiences and meaning making about electricity contain abstract elements, their understanding is limited to their world.

Culture bounds these African American students as their ideas about electricity are based upon their experience. Their understanding is based upon their experiences. For example, Cathy described a circuit as " the things in your basement and you gotta, like if the lights go out or something you gotta push the button in to make them come back on." Clearly her definition is bound to her own reality and experience of lights going out. Maybe Cathy witnessed a family member going down into the basement pushing switches turning the lights back on. In a classroom setting, would the teacher and other students accept Cathy's ideas? What if the other students did not have a basement and have not had exposure to the same situation as Cathy?

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MAKING SCIENCE ACCESSIBLE: STRATEGIES FOR MODIFYING SCIENCE ACTIVITIES TO MEET THE NEEDS OF A DIVERSE STUDENT POPULATION

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The inclusion of students with special needs in the regular classroom has clearly become part of the overall educational landscape. Despite the sincere interest of many teachers to address the educational needs of all of their students (Scruggs & Mastropieri, 1994), the current emphasis on inclusion remains a source of frustration, misunderstanding, and distrust by teachers, parents, and students. Many regular educators are ill-prepared or supported to accept the challenges of teaching students with special needs. All science teachers and educators have their favorite science activities that demonstrate key science concepts. One of dilemmas that they often face is how to modify these activities so that they are accessible to a wider range of students. This presentation will demonstrate some general strategies that can be used to modify activities, and provide some specific examples of modified activities.

Rationale

Science education is in a unique position to serve the needs of students with special needs in that accommodations can easily be made part of the normal variation in instructional modes. Hands-on learning, cooperative groups, dialogue and discussion, and authentic assessment, which figure prominently in current thinking on effective science teaching (Champagne, Newell, & Goodnough, 1996; Gabel, 1995), are also opportunities for accommodating students with special needs (Mastropieri & Scruggs, 1996).

National science education reform efforts emphasize science for ALL students. (National Research Council, 1996; American Association for the Advancement of Science,

1989). These reforms call for quality education for *all* students regardless of cultural background, socio-economic background, physical condition or learning ability. "All students, regardless of sex, cultural or ethnic background, physical or learning disabilities, future aspirations, or interest in science, should have the opportunity to attain high levels of scientific literacy," (NRC, 1996, pg. 22).

Few people would argue with these goals. Implementing these goals, and taking the necessary steps to meet them though can be a confusing and difficult task. As inclusion becomes more of a norm in schools, a wider range of teachers now find themselves responsible for teaching students with a greater diversity of needs. Research indicates that teachers take this responsibility very seriously , but feel ill prepared to do so (Bunch, Lupart, Brown, 1997). Many of these teachers find they lack the familiarity and experience in making accommodations necessary to meet the unique and diverse needs of these learners (Trump & Hange, 1996; Yasutake & Lerner, 1996). This can lead to feelings of isolation and uncertainty when dealing with students who have different needs.

Science teachers are also very concerned with issues of safety; especially in those areas of science where there is increased risk of injury to students due to the nature of the activities. When faced with this setting some teachers choose to "protect" the student by having them take a more passive role in the activity. This may protect them from the possibility of injury, but it also limits their opportunities for learning.

In a study exploring beliefs about teaching those with disabilities, Goodlad (1993) used questionnaires and interviews with general and special education interns and faculty. General educators "commonly viewed themselves as inadequately prepared in many of the specific skills that are generally considered to be important in providing instruction to students with special needs (pp. 235-236)." These teachers rated themselves low on their ability to

individualize instruction and rated their competence to adapt instruction for students with disabilities lower than any other skill.

It doesn't take a great deal of experience for a teacher to quickly learn that modifications or strategies that benefit one student, may limit access for another student. Finding balance and strategies for personalizing the learning opportunities is a daunting task. This often leads them to minimize modifications and move back toward more traditional ways of teaching with the belief that this is fairer to a larger proportion of the students.

Guidelines for Adapting Science Activities

There are a wide range of resources available to help a teacher think about adapting activities. The following list is modified and expands material by Berda and Blaisedell (1998) and the includes strategies used by authors of this paper.

Strategies to support all students

- Don't ignore the disability
- Talk to the student about what types of accommodations they want/need
- Make sure students have a comfortable way of asking for help (journal, question book, e-mail, special signal, etc.)
- Discuss scientists who have disabilities and their contributions whenever possible
- Have students familiarize themselves with the room prior to class and without peers
- Arrange furniture so that all students have clear access to the information being presented
- Speak clearly and naturally
- Be aware of your position in the room and the volume of your voice.
- Write legibly
- Make notes and assignments using the computer so font size can be increased if needed.
- Use simple language when giving directions.

- Provide directions and information in both verbal and written form (large print – 14 pt font or larger)
- Use diagrams and pictures as often as possible
- Give out instructions in advance and repeat just before activity
- Run through the activity and actually demonstrate the steps prior to the activity – model what you want them to do.
- Use cooperative learning strategies and assign roles in the groups
- Use computers to help students organize information and submit written material
- Offer students the option of recording their responses.
- Make labs multi-sensory and or draw on multiple modes of learning.
- Use materials with strong textures and bright, primary colors
- Increase the tactile nature of the materials used.
- Use non-skid shelf liner or mats to keep materials in place.
- Allow students to adequate time for activity – don't rush through the material.

Strategies to support students with Attention Deficit Disorder

- Make sure students understand all the instructions before beginning the lab
- Repeat instructions and have students repeat back to you the instructions.
- Make instructions clear and precise – well defined tasks
- Assign one task at a time
- Provide materials and tools to organize work – charts, computer data bases, data tables, etc...

Strategies to support students with hearing impairments

- Seat the student where they are most comfortable
- Reduce background noise

- Signal for student's attention before speaking
- Keep your face visible when speaking
- Speak slowly and clearly
- Repeat other student questions and comments
- When demonstrating an activity, alternate between speaking and working with the material so that students can focus on one thing at a time.
- Use only one source of visual material at a time
- Use overhead projectors, visual aids and demonstrations as much as possible so that you can face the classroom.
- Use captioned films
- Provide all instructions and assignments in writing
- Supplement sound stimuli in experiments with visual stimuli
- Use new vocabulary in various contexts.
- Work from the concrete to the abstract.
- Provide extra time as needed

Strategies to support students with motor difficulties

- Plan for access problems – all aisles should be 42 – 48 inches wide.
- Alter table height for wheelchair access. Spaces under work surfaces should be 29 inches high, 36 inches wide and at least 20 inches deep. The work surface should be no more than 32 inches off the floor.
- Increase the size of laboratory equipment for easy gripping
- Ask students if they want help before offering it ("Would you like..." rather than "Here, let me....")
- Do not lean on or move a student's wheelchair unless asked

- Have students work with a partner
- Place materials within easy reach
- Be aware that some students may not a strong sense of temperature – they can be hurt themselves when using hot or cold water.
- Provide extra time as needed

Strategies to support students with vision impairments

- Seat the student where they are most comfortable
- Reduce background noise
- Call on the student by name
- Identify yourself and those in the group when you begin a conversation
- Be specific when giving directions. Avoid phrase such as: over there, here, like this.
- Give directions in relation to the student's body
- Verbalize all written notes and instructions
- Be specific when describing what is happening in the experiment. For example, the worm moved 4 centimeters away from the light.
- Let the student know when you are ending the conversation
- Increase the tactile components of labs.
- Keep materials and furniture in the room in the same place.
- Keep things up off of the floor and/or out of walking aisles
- Mark measuring tapes with stables or bead of glue.

Guidelines for helping pre-service teachers and practicing teachers develop skills and strategies to support students with disabilities

The activities and suggestions in this section are divided into three main categories. Building Awareness; Identifying and Developing Modifications; and Planning for Action.

Building Awareness

Show and discuss the Richard LaVoie (Lavoie, 1994; Lavoie, 1997; Lavoie, 1989)videotapes and materials. The tapes and guides are available for purchase through The Public Broadcasting System. These three tapes provide a range of information on definitions and implications for learning disabilities, the implications for learning disabilities and development of social skills; and the implications of learning disabilities for classroom management and discipline issues. While not geared specifically for a science class, they are powerful tools to get students past the "blaming the victim" mentality that many beginning teachers develop when they first have difficulty working with a learning disabled student.

A second awareness activity that is fairly easy to infuse into a teacher education program is to have a pre-service teacher shadow a special education teacher for a day or two and write up their reflection of that experience. A few questions that could be used to get them started include: How many students is the teacher responsible for? What types of disabilities do these students represent? How many general education teachers is the special education teacher working with? How many different disciplines (i.e. science, mathematics, literature, social studies, etc…) is the special education teacher supporting?

Identifying and Developing Modifications

While demonstrating or having methods student explore a typical science activity or inquiry lesson have one member in each group role play a disability. To do this in a methods class provide one student with a pair a chemical safety goggles that have had front panels covered with transparent tape. This allows students to see light and dark shapes, but not clear images. Another student could be asked to wear oven mittens during the activity. One student could wear ear plugs. One student must remain seated throughout the activity. One student could have a length of wooden dowel taped to their arm so that the arm has limited movement, another student could have a dowel taped to their leg above and below the knee for limited range of movement of

the knee. Prepare a task that requires reading or following a set of written directions to complete and black out every other line of text for one of the students. Other modification can be made depending on the size of class and number of groups in the class.

At the end of the activity have the class debrief both the activity and the implications for having a group member that was role playing a disability. Some questions to get the discussion started include: How does the group have to adjust to help the student complete the activity? The group can debrief by brainstorming what tools and resources a teacher in that classroom should have provided. This activity gets them thinking about modification they might include in lesson plans they are writing.

Planning for Action.

Have teachers develop action plans to support students. See sample assignment that follows. The example provided can be used for a methods course or as part of a larger project.

Action Plan -- Learning Styles

As science teachers we have a responsibility to teach all students. Each classroom will have students with a wide range of learning styles and abilities. How are you going to ensure that you are meeting the needs of your students? What resources are available to help you support students? "Learning Styles" is a huge category and can mean many different things to different people. To limit the focus of this action plan choose one of the following categories and address three areas in each of this categories.

A. Learning Disabilities (dyslexia, attention deficient disorder, etc.)

B. Physical Limitations (hearing, visually, or mobility impaired, etc.)

C. Gardner's 7 Intelligences

D. Your proposed category (Check with me about additional categories or interests that you have that might fall under learning styles.)

Use the following to guide your development of an action plan. This is not meant to be the way that you present your plan. Several of these items could be grouped together. How you develop your plan and present it is a personal decision, but these are the items that you will be evaluated on (see grading rubric).

- ☐ Description of situation or rationale for need for action. (Minimum of 2-3 paragraphs)
- ☐ Background information (Are there appropriate laws, regulations mandating support? Is the school or another agency providing support? Is there a school focus or school support for this area?)
- ☐ Identification of individuals involved. (Detail who is involved and what responsibility each individual has)
- ☐ Identification of available resources.
- ☐ Identification of 3-5 options for each area.
- ☐ Prioritization of options (which would you do first, second etc....).
- ☐ Follow-up plans (How are you going to that that what you have implemented is working or if you need to modify your plan?).

To get you started following here are some ideas that past students have used or thought about using:

- ☐ Write this up as a newsletter or news paper article telling the reader your plans,
- ☐ Use something PowerPoint and think of it as a presentation to a school and/or parents;
- ☐ Use a graphics program to show plan as a concept map or flow chart
- ☐ Use HyperStudio with links and buttons
- ☐ Take an existing lesson plan or unit and annotate it to demonstrate your plan

This is a time for you to integrate all the resources you have available, things such as: What you have learned about adolescent development; Learning styles; Your special education

inclusion course; Course discussions; The film "How difficult can this be?"; Class materials/resources; Your cooperating teacher and other school resources.

Science Activities Modified to Meet the Needs of Students with Disabilities

The following three activities have been modified to increase the variation of sensory and learning styles than may by typical of this type of activity. These sample lessons are provided so show a few of the modification that can make science more accessible to students with disabilities. Activities are provided in three areas:

- Science Skills – Sampling
- Life Science – Population Dynamics: Survival Strategies
- Physical Science – Refraction

Science Skills - Sampling

This provides an introduction to sampling procedures that are commonly used to explore science concepts.

Science Concepts Address:

- Sampling
- Graphing
- Estimation
- Population dynamics
- Survey dynamics
- Simple calculations

Materials per student team or pair

- Folding checker board (or paper marked out in a grid pattern – 5 cm squares work well)
- Colored glue or pipe cleaners

- 6 different color Beans or large beads (pony beads work well). – 100 of one color (color A – 200 if doing the extension; 25 of each of the other 3 colors (colors B, C, & D – 100 of each if doing the extension); 15 each of colors two different colors (colors E & F (50* of each if doing the extension)
- Large shirt size box - optional
- Zipper-style sandwich storage bag
- 7 Small cups (8-10 ounce size)
- Graph paper or paper to make graphs
- Markers or colored pencils
- *Optional – empty grated cheese plastic canisters (like the type pre-grated parmesan cheese is often sold in – that have the sprinkle and pour options in the lid).

<u>Directions</u>

Pre-lab set up:

In the sandwich back – count out 100 of color A, 25 each of colors B, C & D, 15 of color E and 10 of color F (total of 200 beads in this bag). The contents of this bag go in one of the cups. Remaining beads/beans go into remaining cups – one cup per color. Using glue outline the squares of the checkerboard or paper grid. Using the glue raises the boarders of the squares and allows individuals with vision limitations to still be able to count. If you do know want to use glue you can also use pipe cleaners form a square the size of one of the squares of the checkerboard. This can then be placed randomly on the board. A shirt box can be used to hold paper grid or checkerboard.

Activity Directions

- Count the number of squared on the checkerboard or grid. Record this number in the data table.
- Pour/scatter the beads/beans in the cup evenly onto the grid. A grated cheese container works well for this in place of the cup.

- Choose one of the squares in the grid. (The square chosen should have at least one bead/bead in it. The process of choosing a square can be done a variety of ways depending on the size of the grid. Students could number and letter the x and y-axis and have these numbers and letters in a basket to randomly draw coordinates. If the grid is smaller than 6 x 6 two position could be determined by numbering off the grid and rolling a dice for location (first roll x-axis second role y-axis). Younger students could close their eyes and randomly put their finger down on a square.
- Record the number of beads/beans of each color in the chosen square on the data table.
- Multiply the number of beads/beans of each color by the total number of squares in the grid. Enter that number on the data table.
- Pour the beads back into the container.
- Repeat steps 2 – 6 two more times. For a total of 3 trials.
- Average the 3 trials and record the average in the data table.

Assessment Strategies/Questions

Are the estimated population and the real population close to the same number? How do these numbers differ?

Explain what may cause a difference.

Why do you average 3 different trials rather than using only 1 trial?

When would you use a sampling procedure like this?

Create a graph showing the differences between calculated populations and real populations.

Design an experiment that would use this type of sampling, include in this design that data form that could be used to collect the data.

Follow-up options and extensions

Option #1: Using the activity total numbers assuming 100% reproduction – add beads to container. For example if experimental number for color A was equal to 85 add an additional 85 beads of color A to container. Repeat the trials with these new numbers.

Does accuracy increase or decrease with larger initial populations?

Option #2: Fill 1 one-liter beaker with a mixture of beads. Have students measure out 10 milliliters of beads and calculate the population of beads in the liter container.

How is this method of sampling similar and/or different from the technique used in this activity?

When would you use this type of sampling and estimation?

Option #3: Use a digital camera to take a picture of the grid and population. Is this strategy as accurate is a direct observation? Why or why not?

Option #4: Scatter the population over an area that is not marked out in a grid. Have students design a method for determining the population.

Option #5: Provide students with a digital picture of a population and an overhead transparency marked in a grid pattern to do this activity. This can lead to a nice exploration of cartography and how maps are made of planets or inaccessible areas of earth using satellite images.

Additional Teaching Suggestions

- Vary the size of the population pieces to accommodate students who have motor difficulties.
- Vary the size of the grid using flooring tiles for the squares and marking off a grid with masking tape.

Comparison to real numbers.	
Total Population	Population by color

Real = 200	Activity	Real numbers A = 100 B = 25 C = 25 D = 25 E = 15 F = 10	Activity A = B = C = D = E = F =

Sample Data Table

	Total number of squares	**Number of individuals in one square.**	**Estimated population of each color**	**Estimated total population**
Trial #1		A = B = C = D = E = F =	A = B = C = D = E = F =	
Trial #2		A = B = C = D = E = F =	A = B = C = D = E = F =	
Trial #3		A = B = C = D = E = F =	A = B = C = D = E = F =	
Color A = **Color B =**			**Average estimated population by color**	**Average estimated total population.**
Color C = **Color D =** **Color E =** **Color F =**			A = B = C = D = E = F =	

National Science Standards

Content Standard A: Understanding about scientific inquiry (K-4) pg. 123

- Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.
- Scientists use different kinds of investigations depending on the questions they are trying to answer. Types of investigations include describing objects, events and organisms; classifying them; and doing a fair test (experimenting).
- Simple instruments, such as magnifiers, thermometers, and rulers provide more information than scientists obtain using only their senses.
- Scientist develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations.
- Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigation.
- Scientists review and ask questions about the results of other scientists' work.

Content Standard A: Understanding about scientific inquiry (5-8) pg. 148

- Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discover of new objects and phenomena; and some involve making models.
- Current scientific knowledge and understanding guide scientific investigations. Different scientific domains employ different methods, core theories, and standards to advance scientific knowledge and understanding.
- Mathematics is important in all aspects of scientific inquiry.

- Technology used to gather data enhances accuracy and allows scientist to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.
- Science advances through legitimate skepticism. Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate the explanations proposed by other scientists by examining evidence, comparing evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence and suggesting alternative explanations for the same observations.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.

Content Standard A: Understanding about scientific inquiry (9-12) pg. 176

- Scientists usually inquire about how physical, living, or designed systems function. Conceptual principles and knowledge guide scientific inquiries. Historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists.
- Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories.
- Scientist rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data,

thereby contributing to the advance of science. The accuracy and precision of the data and therefore the quality of the exploration, depends on the technology used.

- Mathematics is essential in scientific inquiry. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations and communicating results.
- Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modifications; and it must be based on historical and current scientific knowledge.
- Results of scientific inquiry – new knowledge and methods – emerge from different types of investigations and public communication among scientists. In communicating and defending the results of scientific inquiry, arguments must be logical and demonstrate connections between natural phenomena, investigations and the historical body of scientific knowledge. In addition, the methods and procedures that scientists used to obtain evidence must be clearly reported to enhance opportunities for further investigation.

Life Science – Population Dynamics: Survival Strategies

A wide variety of strategies allow living organism to survive in their environment. The following set of activities help students understand how and why some of these strategies are effective.

Science Concepts Address:

- Camouflage
- Preditor/prey relationships
- Mimicry
- Population dynamics

Materials per student team or pair: Birds and Worms – Project Learning Tree(American Forest Foundation, 1993)

- 100 small objects to represent worms or bugs, some suggestions: Multicolored pipecleaners – cut in 3-4 inch lengths (20 segments of 5 different colors – works well), pieces of yarn, paper shapes, paper clips. If done outdoors it is best to keep to biodegradable materials such as: beans, dog food, colored pasta. Be sure to start out with equal numbers of each color, for example 25 each of 4 colors, 20 each of 5 colors, 10 each of ten colors. You will need double of these materials for the extension. At least one of the colors should match the "field" or habitat.
- A large piece of white newsprint or poster paper.
- Markers
- Paper
- 1 sheet of white paper (8.5" x 11") for each team
- Pencils
- "Field" or Habitat – If doing this indoors it is helpful for clean up to do this on a sheet of wrapping paper, blanket, sheet or similar material. If doing this outdoors you may want to mark off the boundaries of the habitat.

Directions – Birds and Worms

Pre-lab set up:

- Count out initial population – 100 works well and makes for easy graphing but is not required. Record how many of each color you start out with on one side of the white paper.
- Determine your habitat location and spread out the "field" or mark boundaries of habitat
- Scatter worms/bugs in the habitat.

Activity Directions

- Divide the group into equal sized teams. Three to five teams per class works well.

- Describe the activity to the class. For this activity the students represent hungry birds. Scattered in the habitat is a variety of types of food for them. Show them what the food looks like or describe it to them.
- Have students line up within their teams. Students should number off within their team in the order they are in line.
- When the teacher says "Go" the first bird in each team will "fly" over the habitat and pick up the first piece of food that they see. When they get back to their team the next person "flys" over the field. The round is over when each member of team has gotten a piece of food.
- Using the large piece of paper make a chart with as many columns are there are members of each team. Each column is representative of their placement in the line. The students should place their worm in the column representative of their position in the line. A sample chart follows:

Team Name	1st Bird	2nd Bird	3rd Bird	4th Bird	5th Bird	6th Bird	7th Bird	8th Bird

- Have students count the number of each color of bird/bug that was collected by the class.

Option 2 or extension

- Have a white sheet of paper place about 1 meter in back of the last person in the line. Draw columns on the paper and number each column to correspond with student numbers Each bird puts down the piece of food they picked up on the white piece of paper. The food should be placed in the order it was picked up. That bird moves to the back of line and waits for it's turn to "fly" over the field. Each bird should visit the habitat 2-4 times depending on class size and amount of food available. At the end of the activity the white paper should have all the food collected by that bird team in the order it was picked up.
- Collect class data on data chart similar. See assessment questions below. The activity done in this way helps students understand that when food supplies are less plentiful, camouflage is less beneficial than during times when food is plentiful. Another way of documenting this is have student use a stop watch and time how long it takes their team to get food for each round.

Assessment Strategies/Questions

- Prepare a graph representing the information gathered.
- Is there any pattern in the order the worms/bugs are found? Does this pattern have any significance?
- What color was the easiest to find? What color was the hardest to find?
- What type of worm/bug has the best camouflage for this environment and why?

Follow-up options and extensions

- Using the same worms/bug try the activity on a different colored "field." How did this change the results?
- In place of color use texture or shape. One way of doing this is to fill a large bowl with marbles. Place in this bowl "food" pieces in a variety of shapes and textures such as: dice, pasta, yarn, fabric, ping pong balls, nuts, bingo chips, etc.
- An extension described in the FOSS Animals 2 x 2 kit [Lawrence Hall of Science, 1992] – has the teacher prepare a large paper grocery bag lined with newspaper. Fill the bag with shredded newspaper. Cut out equal numbers of colorful fish from construction paper, and twice that number of newspaper fish. For example: 20 red fish, 20 yellow fish, 20 blue fish, 20 green fish, 40 newspaper fish. Record data from "fishing trip" similar to that for "Birds and Worms."

Materials per student team or pair – Safety in Numbers

- 10 – 20 marbles or other small objects to represent birds
- Solid colored cup to hold objects
- Mailing tube for posters, or card board tube from wrapping paper (coffee cans or oatmeal boxes also work well)
- Small box – for optional activity

Directions – Safety in Numbers

Activity Directions

- Have one student represent the birds of the flock. The other partner represents the predator for the birds. Their job is to determine the size of the flock.

- The individual representing the flock chooses a number of "bird" holding them so that the predator cannot see how many there are drops them down the tube or into the canister. Based on the sound the predator estimates how many birds are in the flock.

Real Population	Estimated Population

Option 2 or extension

- In place of dropping objects. A small box with items placed in it and then allow the predator to shake the box to determine the population can also be used.

Assessment Strategies/Questions

Is there more accuracy in estimating small numbers of birds in a flock or larger numbers?

What factors influenced the accuracy of the estimate?

National Science Standards

Content Standard A: Understanding about scientific inquiry (K-4) pg. 123

- Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.
- Scientists use different kinds of investigations depending on the questions they are trying to answer. Types of investigations include describing objects, events and organisms; classifying them; and doing a fair test (experimenting).
- Simple instruments, such as magnifiers, thermometers, and rulers provide more information than scientists obtain using only their senses.

- Scientist develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations.
- Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigation.
- Scientists review and ask questions about the results of other scientists' work.

Content Standard A: Understanding about scientific inquiry (5-8) pg. 148

- Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discover of new objects and phenomena; and some involve making models.
- Current scientific knowledge and understanding guide scientific investigations. Different scientific domains employ different methods, core theories, and standards to advance scientific knowledge and understanding.
- Mathematics is important in all aspects of scientific inquiry.
- Technology used to gather data enhances accuracy and allows scientist to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.
- Science advances through legitimate skepticism. Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate the explanations proposed by other scientists by examining evidence, comparing evidence, identifying faulty

reasoning, pointing out statements that go beyond the evidence and suggesting alternative explanations for the same observations.

- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.

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Physical Science - Refraction

This is a modification of the penny in a cup activity often done to demonstrate the concept of refraction.

Science Concepts Address:

- Refraction
- Implications of thickness of atmosphere and how it affects the bending of light.

Materials per student team or pair

- 2 drinking cups
- 2 shiny pennies or other coins
- modeling clay – 2 marble sized pieces
- water

Directions

Place the one piece of clay in the center of each cup.

Place the coin on top of the clay so that the coin in centered in the bottom of the cup.

Fill one cup 1/2 to 3/4 with water.

Place both cups on the edge of the table. The cups should be side by side at the edge of the table.

Stand close to the table.

Slowly move back from the edge of the table while observing the cups.

Stop when you can no longer see the coin in either cup.

Assessment Strategies/Questions

Describe what you observed and develop and explanation for this observation.

Diagram your explanation.

Does the distance change on the eye level of the observer? Explain why or why not.

Follow-up options and extensions

Try different liquids such as cooking oil, rubbing alcohol, corn syrup. Mark on the floor the spot where the coins disappear for each liquid. What patterns can you detect?

Have a student hold a string at the corner of their eye and a partner hold the other end of the string parallel to the coin position, using a protractor determine the angle at which each coin disappears. How does this change based on the liquid used?

National Science Standards

Content Standard B: K-4 pg. 123

As a result of the activities in grades K-4, all students should develop on understanding of

- properties of objects and materials
- position and motion of objects
- light, heat, electricity and magnetism*

*Expansion of this concept in regards to this activity (pg. 127)

Light travels in a straight line until it strikes an object. Light can be reflected by a mirror, refracted by a lens, or absorbed by the object

National Science Standards

Content Standard B: 5-8 pg. 155

Transfer of energy

Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object – emitted or scattered from it – must enter the eye.

.Modified and expanded version of a published activity. [VanCleave, 1991]

Conclusion

For science to be inclusive, science educators and teachers need to start making the effort to rework and restructure science curriculum to meet the differing ability levels of special needs students. There will always be difference in the abilities of people to do science, however, until we begin to address directly science concepts critical for living, we will continue to have a wide range in the quality of science education offered to our nation's students. We must learn to appreciate and embrace some of the teaching strategies and ways of working with students that teachers in other disciplines use. If we don't make the effort to

change how we present science, science will always be seen as elitist and not essential learning for all students.

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AN ENVIRONMENTAL EDUCATION NEEDS ASSESSMENT OF K-12 TEACHERS

Yvonne Meichtry, Northern Kentucky University

An environmental education needs assessment of K-12 teachers was conducted as part of a larger project that explored the challenges of preparing Northern Kentucky University (NKU) for the establishment of a regional Center for Environmental Education. The Center at NKU is to be part of a network of Centers located throughout Kentucky. The General Assembly mandated the creation of the Centers in KRS157.915 (3) and, in KRS157.99 (3), establishing the Kentucky Environmental Education Council (KEEC) to help coordinate the activities of this network of Centers. The charge of these Centers is to promote coordination, collaboration, and consistency in the environmental education of university students, elementary and secondary teachers, and the general public (Eller, 1999).

Initial preparations for the establishment of the regional Center at NKU began with a project funded by the Center for Integrative Natural Sciences and Mathematics (CINSAM) at Northern Kentucky University. The goal of this project was to identify current and future needs and to explore innovative methods of enhancing the delivery of environmental education in the Northern Kentucky region. These efforts were aimed at empowering NKU to assume new roles and responsibilities related to the Center for Environmental Education once it was established as part of the state network of Centers.

The activities accomplished by the overall CINSAM project included the following: 1) Identified the needs & programs of formal and non-formal environmental educators in the region; 2) Obtained information from existing Environmental Education (EE) Centers in the state

about their mission, objectives, and programs; 3) Surveyed the programs of other colleges involved with EE in the region; 4) Investigated existing EE curricula for consistency with state education standards; 5) Explored ways to connect EE with the social science, humanities, economics, and teacher education departments on campus; and 6) Summarized and shared the project findings with the KY Environmental Education Council, university community, and other project participants.

This paper focuses on the results of the needs assessment conducted with teachers as part of Activity 1 identified above. The methodology used to assess teachers' needs is described and the results of the needs assessment are summarized. Follow-up initiatives are then presented. The paper concludes with the implications of this project to environmental educators.

Methodology and Results

The overall purpose of the needs assessment was to determine the priority EE program and training needs of teachers. The assessment methodology consisted of two parts. The first part was a written survey completed by teachers. The design and content of the survey was developed with input from members of the Northern Kentucky Environmental Education Coalition (NKEEC). The NKEEC includes educators from local schools, organizations, and state agencies who are involved in environmental education. Once an analysis of the survey results was completed, a follow-up focus group discussion was conducted to gain additional insights into the teachers' survey responses.

Survey Methods

The survey instrument, presented in the Appendix A, was designed and distributed to 87 teachers. These teachers had been identified as "Contact EE Teachers" for their school buildings.

In this role, they help to distribute mailings and announce EE opportunities for teachers. Of the 51% of teachers who responded, 24 taught at the elementary level, 5 at the middle grades level, and 16 at the secondary level. There were 30 schools represented from 11 districts in 3 counties. The schools were representative of both the public and private sectors.

Survey Results

An analysis of the survey results provided information about what teachers are currently doing, the format of training they would like to see offered, and the level of need they have for various environmental education (EE) program-related services, opportunities, and training.

What Teachers Are Currently Doing

The results, presented in Table 1, indicated that a large majority of teachers are teaching about the environment and environmental issues. There are, however, some who are not. Almost half of the teachers reported having guest speakers, taking field trips, and involving students in action projects. Thirty one percent of the teachers teach in an outdoor setting and 22% have student environmental clubs.

Table 1

Percentage of Teachers Presently Doing Various EE Activities

Percent of Teachers	Teaching Activities
91%	Teach about environmental issues
89%	Teach about the environment
47%	Have guest speakers/programs
44%	Take environmental field trips
42%	Involve students in action projects
31%	Teach in an outdoor setting
22%	Have student environmental clubs

Training Format Desired

As shown in Table 2, the greatest percentage of teachers indicated they would like to see training offered as inservices during the school year. While 49% of the teachers reported wanting summer workshops, only 24 % indicated they would like training offered through university courses for credit. Taking weekend workshops was the least popular choice, with only 20% selecting this type of offering.

Table 2

Training Teachers Would Like to See Offered

Percent of Teachers	Training Format
60%	Teacher inservice during school year
49%	Summer workshops
24%	University courses for credit
20%	Weekend workshops

Level of Program Needs

Teachers were asked to rate the level of need they had for EE services as high, moderate or low. The results, presented in Table 3, revealed that a range of 41%- 91% of teachers rated the 11 services listed as a high level need. The greatest percentage of teachers reported funding as a high level need.

Table 3

Level of Need for EE Services & Opportunities

Program Needs	High need	Moderate Need	Low need
Funding for Activities & Resources	91%	7%	2%
Field Trip Opportunities	83%	12%	5%
Curriculum Resources	74%	21%	5%
Lesson & Curriculum Ideas	70%	25%	5%
Mailings of EE Information	64%	33%	3%
Speakers	63%	33%	5%
Professional Development & EE Training	62%	31%	7%
Development of Teacher Networks	59%	31%	10%
Meetings to Share with Others	51%	28%	21%
Outdoor School Site	50%	29%	21%
Student EE Clubs	41%	34%	24%

Teachers were also asked to priority rank their highest three program needs. As shown in Table 4, the greatest percentage of teachers ranked funding as their number one service need, followed by lesson and curriculum ideas as the second highest need, and field trip opportunities as the third highest need. The point system shown in Table 4 was calculated by assigning a numerical value to the first, second, and third highest need as follows: Highest need = 3 points, 2nd highest need = 2 points, & 3rd highest need = 1 point. These points were assigned to each respondent's ranking for each of the 11 needs listed in the table.

Table 4

Rank Order of Highest 3 EE Service Needs

Program Needs	Overall points	First	Second	Third
Funding for Activities & Resources	53	24%	20%	17%
Lesson & Curriculum Ideas	38	12%	24%	7%
Field Trip Opportunities	33	10%	22%	7%
Curriculum Resources	25	10%	7%	17%
Professional Development & EE Training	22	12%	2%	12%
Speakers	22	10%	10%	5%
Outdoor School Site	19	10%	2%	12%
Mailings of EE Information	6	2%	0%	7%
Meetings to Share with Others	5	2%	0%	5%
Student EE Clubs	3	0%	2%	2%
Development of Teacher Networks	2	0%	2%	0%

Level of Need for EE Training

Table 5 shows the percentages of teachers who rated the level of need they had for EE training. While the greatest percentage of teachers reported training in regard to the availability and use of curriculum to be a high level need, it is evident that teachers would benefit from training in each of the areas listed below. Although training about what EE is was rated as a high level need by the least percentage of teachers, a combined 44% of teachers did rate it as a high or moderate level need.

Table 5

Level of Need for EE Training

Training Needs	High Need	Moderate Need	Low Need
Availability & Use of Curriculum	64%	18%	18%
Technology	59%	24%	17%
Development & Use of Outdoor Sites	58%	20%	20%
Program of Studies Alignment	58%	13%	30%
Teaching Strategies	53%	26%	21%
Funding Sources & Grant Writing	50%	33%	18%
Use of Local Nonformal EE Sites	50%	29%	21%
Integration of EE	50%	28%	23%
Teaching About Environmental Issues	46%	31%	23%
Content Knowledge	28%	36%	36%
What is EE?	13%	31%	56%

Teachers also rank ordered their three priority training needs. As shown in Table 6, the greatest percentage of teachers ranked the development and use of outdoor learning sites as their number one training need, followed by the KY Program of Studies alignment as the second highest need and availability and use of curriculum as the third highest need.

Table 6

Rank Order of Highest 3 EE Training Needs

Training Needs	Overall Points	First	Second	Third
Development & Use of Outdoor Sites	31	18%	11%	5%
Program of Studies Alignment	30	18%	11%	3%
Availability & Use of Curriculum	26	5%	16%	21%
Funding Sources & Grant Writing	24	13%	5%	8%
Content Knowledge	17	11%	3%	8%
Technology	16	8%	5%	8%
Use of Local EE Sites	15	3%	13%	5%
Integration of EE	13	0%	16%	3%
Teaching About Environmental Issues	9	3%	3%	11%
What is EE?	3	3%	0%	0%
Teaching Strategies	2	0%	0%	5%

Comparative Analysis of Grade Level Needs

To determine if there were any differences between the service and training needs of elementary and middle school/secondary teachers, a comparative analysis of the results was done. No significant differences were found.

Focus Group Methods and Results

A 90-minute focus group discussion was conducted to gain more in-depth information about the environmental education needs of teachers that had been assessed by the survey. The seven teachers who participated consisted of two elementary teachers, two middle school teachers, and three high school teachers. Each of these teachers had participated in the survey and had received a written summary of the survey results that had been mailed to all respondents.

The focus group meeting consisted of three parts: 1) Introductions of participants and facilitators followed by a brief overview of the focus group process, 2) Focus group discussions on several questions and 3) Reconvening of the entire group to share results and prioritize needs. There were three focus groups which were designated as elementary, middle school, and high school. Following is a listing of the small group discussion questions and a summary of the results:

1. In what specific ways would funding be helpful to the environmental education efforts of teachers?

Teachers remarked that no school funding has been earmarked for environmental education because it is not a Core Content area on which K-12 students are tested as a part of the state standards assessment program. Instead, interested teachers have had to seek funding from various small grants and have received supplies from businesses such as nurseries and agricultural supply retailers. The teachers reported that a clearinghouse for information on potential funding sources would be a very helpful service.

2A. In what specific ways would field trips be helpful to the EE efforts of teachers?

Low-cost, nearby field trips were especially desirable to the teachers. They reported that summary information about field trips through a web site or newsletter would be a useful service. The teachers strongly advocated sponsoring field trips to different sites on campus led by NKU science education students.

2B. What are the obstacles to taking field trips?

The obstacles reported by teachers centered on transportation issues, time constraints, scheduling within schools, and coordination with other classes. School bus schedules and funding were two constraints related to transportation. Scheduling within schools was more of a problem for departmentalized high schools and middle schools. Students missing other classes due to a field trip posed a problem for both the students and teachers.

3. How would you envision an outdoor site being used at your school for EE?

The teachers believed environmental education sites should provide hands-on learning opportunities to be integrated across all disciplines. They acknowledged that some teachers would probably never use the site, but think most would, if they understood how. Maintenance of the site was recognized as an issue by all of the teachers. It was noted that some volunteer help might be needed to maintain outdoor classrooms.

4A. What are the best ways to recruit teachers to participate in EE opportunities?

The teachers indicated that teachers respond to personal invitations from other teachers or from an institution or organization they respect such as NKU or a county Conservation District. Incentives such as stipends and credit were reported to be desirable. They also reported that free curriculum materials and lesson ideas that can readily be used in their classrooms make new learning opportunities more attractive to teachers.

4B. Describe the nature of professional development that is most useful to teachers.

Hands-on, interdisciplinary workshops were considered to be most useful by the teachers. Professional development that encourages networking with other teachers was also reported to be very desirable.

5. What are some ways you envision a Regional EE Center housed at NKU being most useful to teachers?

Teachers ranked a Regional Center very high on their list of environmental education needs. They indicated that, ideally, such a Center would house nature guides, curricular materials, videos, and other materials that could be loaned to teachers. The loaning of field supplies (e.g. hip waders and nets) for special studies was also a service considered potentially useful by teachers. Having a frequently updated web site with information on field trips, an environmental calendar, and ways for teachers to share ideas was considered a useful function of the Center by the teachers.

The teachers all felt it would be ideal to have an outdoor learning site on the campus of NKU. They envisioned two primary uses of such a site. One use would be a field trip site to which K-12 teachers could bring their students for learning about the environment. Using this site as a lab-school concept, where K-12 students are taught by university students, was an idea greeted with much enthusiasm. The other primary use of this site that teachers expressed a need for related to professional development opportunities for teachers. They stressed the importance of developing the site at NKU to model what teachers can actually do on their own school grounds. They explained that, this way, the outdoor site on campus could serve as a model to train teachers how to develop such a site at their school and how to develop and use curricula in such a site.

At the end of the focus group sharing, the teachers were asked to rank their top three environmental education needs/priorities. Three of the seven teachers rated the establishment of an environmental education center as their top priority. Also ranked high was a land lab/outdoor

classroom at NKU where K-12 students and preservice teachers could learn together, enhancing the education experience for both. Teachers also were very interested in workshops with practical and immediate applications and in methods to integrate book knowledge with outdoor classroom sites. In short, the participating teachers' priorities indicated the need for an expanded role for NKU in environmental education and training.

Follow-Up Initiatives

Although the EE Center in the region had not yet received the funding to be established, the results of this needs assessment were put to immediate use. The results were shared with other environmental educators in the region, resulting in a collaborative effort between university faculty, K-12 teachers, and nonformal environmental educators in the region to plan and conduct an after-school outdoor classroom workshop for teachers. The development and use of outdoor classrooms was selected as the focus of this workshop because of the priority need for such training expressed by teachers in the survey and focus groups interviews. Over 50 teachers attended the workshop. The evaluations of the workshop indicated the high interest of teachers in additional workshops. A reception that will showcase local EE field trip sites and a follow-up, all-day field trip to visit such sites was thus planned.

The development of an outdoor environmental education site on the NKU campus is another recommendation being implemented. The facility being planned will be used to address many of the EE needs of teachers reported in the survey results and will encompass many of the recommendations expressed in the focus group interview. The intention is to develop a site that can be used in the ways recommended by teachers during the focus group interviews; for K-12 student field trips and as a model during professional development activities for developing such

a site and using it as a teaching resource. Preservice teachers and NKU students from other departments, such as Environmental Science and Biology, will be involved in the planning and development of the site. In addition, preservice teachers will have the opportunity to develop and use lessons to teach groups of K-12 student who visit the site during field trips.

The site will facilitate the delivery of the specific types of professional development experiences for which the teachers expressed a need. These experiences include maintenance of an outdoor site, the alignment of EE with the Kentucky Program of Studies, the integration of EE across the curriculum, the integration of book/in-classroom learning with outdoor learning, the availability and use of EE curriculum, and lesson ideas. In addition, the site will offer the context for teacher training which was reported by the teachers to be relevant and practical for their needs and would provide for the type of hands-on instruction that the teachers reported was valued.

In addition to the expressed need of teachers for an outdoor classroom at NKU, the rationale for the development of such a site is based on current research that supports the use of the natural environment as a learning setting. Evidence gathered from 40 schools in a national study conducted by the State Education and Environment Roundtable indicated that students learn more effectively within an environment-based context than within a traditional educational framework (Lieberman & Hoody, 1998). Results from this study showed that when teachers used the natural environment as an educational setting, students had better performance on standardized measures of academic achievement in reading, writing, math, science, and social studies; reduced discipline and classroom management problems; increased engagement and enthusiasm for learning; and a greater pride and ownership in accomplishments. The results of the study also indicated positive outcomes for teachers. These outcomes included greater

enthusiasm and engagement, greater use of interdisciplinary approaches, greater collaboration with other teachers, and an increased willingness to use new teaching methods.

Funding was a great need of teachers according to both the survey and focus group results. Funding sources such as existing state grant programs, federal programs, private foundations, and local businesses will be sought for the purpose of developing the outdoor site on campus and acquiring curriculum, technology, and equipment resources to enhance instruction at the site. Using external funds in such a way will, again, serve as a model for teachers in regard to how they can acquire such funding. The identification of funding sources and insights about successful fundraising are planned as topics to be incorporated into professional development experiences for teachers.

Implications

Some caution should be exercised when generalizing the results of this study to other populations. The teachers in this study all served as EE Contact Teachers for their school. The EE Contact teachers have expressed an interest in EE and have agreed to distribute information about EE to other teachers in the school. This sample thus represents a population of teachers who have an inherent interest in EE and who are more likely to have skills and knowledge about teaching EE than the general population of teachers. Given that a high percentage of teachers in this study have either a high or moderate level need for each of the eleven areas of program and training needs listed on the survey, it might be assumed that teachers in a more generalized population of teachers would express an even higher level of need.

One major implication of the results of this project is that a great percentage of teachers

have either a high or moderate level of need for each of the eleven areas of training listed on the survey. The priority program needs of teachers to be addressed by environmental educators, as evidenced by the results of this assessment, included funding opportunities, lesson and curriculum ideas, and field trip opportunities. Priority professional development needs were evident in the areas of outdoor education site development and use, the use and alignment of EE curriculum with state standards, and the availability and use of curriculum resources. The two preferred formats for professional development experiences were inservice presentations during the school year and workshops. A smaller percentage of teachers expressed interest in university courses and weekend workshops.

Both formal and nonformal environmental educators can use such results from needs assessments in the planning of professional development opportunities for teachers. In addition to planning professional development workshops, such results can be used by university teacher education faculty to design formal coursework and EE programs for inservice teachers.

In addition to helping to identify and address the priority needs of teachers, this project can benefit others by serving as a model in regard to needs assessment methodology and use. The combined methodology of the survey and follow-up focus groups is a process that yields useful information for a variety of purposes and populations.

This project also serves as a model for the collaborative design and use of a needs assessment for teachers. Collaborative participants in this project were members of the Northern Kentucky Environmental Education Coalition, which is represented by the County Conservation Districts, Cooperative Extension Service, Environmental Resource Management Center at NKU, regional and local parks personnel, K-12 teachers, and university faculty. Environmental

educators from each of these affiliations provided input into the design and content of the survey, helped to distribute the results, and assisted with planning and conducting initiatives to implement the results.

Conclusion

This project can serve as a model for conducting EE needs assessments with a variety of populations in a number of different settings. Populations other than K-12 teachers to be considered include pre-service teachers, pre-school teachers, university faculty in teacher education and other university departments involved in environmental education, postsecondary students, local service groups that desire to be more proactive in the stewardship of the environment, and the general public. A needs assessment might also be considered in a number of different settings, ranging from more localized settings such as a single school district or school to a statewide setting. While a local setting would allow for specific needs to be identified and addressed at the local level, a statewide assessment could be analyzed by region, taking into account demographic factors which have an impact on the planning and offering of environmental education opportunities.

An increasing number of states are aligning state standards in a variety of subject areas with NAAEE's *Guidelines for Learning K-12* (1999). As teachers prepare to address the *Guidelines for Learning K-12* and teacher educators prepare to implement the *Guidelines for the Initial Preparation of Environmental Educators* (1999), studies such as this needs assessment will prove to be increasingly valuable.

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Appendix A

Needs Assessment

How Could a Region 4 Environmental Education Center Meet Your Needs?

Name of District and School

____

Grade Level(s) Taught ________________________

Subject Area(s) Taught

____

Presently Do at My School

___ Teach about the environment

___ Teach about environmental issues

___ Involve students in action projects

___ Teach in an outdoor setting

___ Take environmental field trips

___ Have guest speakers/programs

___ Have student environmental clubs

Other ________________________

Training Would Like to See Offered

___ Teacher inservice during school year

___ Weekend workshops

___ Summer workshops

___ University courses for credit

___ Other ________________________

Are you a member of *Kentucky Association for Environmental Education?* Yes No

Have you ever attended a *KAEE* Conference? Yes No

ENVIRONMENTAL EDUCATION NEEDS

EE Services: Please rate your level of need for EE services, using the scale below:

	Low		Moderate		High
1. Outdoor school site	1	2	3	4	5
2. EE professional development & training	1	2	3	4	5
3. Funding for activities and resources	1	2	3	4	5
4. Mailings regarding EE information & opportunities	1	2	3	4	5
5. Curriculum resources	1	2	3	4	5
6. Field trip opportunities	1	2	3	4	5
7. Meetings to share, network, and learn	1	2	3	4	5

8. Lesson plan and curriculum ideas	1	2	3	4	5
9. Speakers	1	2	3	4	5
10. Student clubs	1	2	3	4	5
12. Development of teacher networks	1	2	3	4	5
13. Other ________________________	1	2	3	4	5

Please rank order your top three service needs, with 1 being your highest need, 2 your second highest need, and 3 your third highest need:

1. 2. 3.

<u>EE Training Needs</u>: Please rate your level of need for EE training in the following areas, using the scale below:

	Low		Moderate		High
1. What is environmental education?	1	2	3	4	5
2. Content knowledge about the environment	1	2	3	4	5
3. EE teaching strategies	1	2	3	4	5
4. Availability & use of curriculum resources	1	2	3	4	5
5. Integrating EE with other subjects	1	2	3	4	5
6. Teaching about environmental issues	1	2	3	4	5
7. Alignment of EE with Program of Studies (Core Content)	1	2	3	4	5
8. Technology use relating to EE	1	2	3	4	5
9. Development & use of outdoor EE site	1	2	3	4	5
10. Funding sources & grant writing skills	1	2	3	4	5
11. Use of local nonformal EE sites	1	2	3	4	5
12. Other ________________________	1	2	3	4	5

Please rank order your top three training needs, with 1 being your highest need, 2 your second highest need, and 3 your third highest need:

1. 2. 3.

Please comment in any way you think would be helpful for purposes of this survey:

LANGUAGE DEVELOPMENT AND SCIENCE INQUIRY: A CHILD-INITIATED AND TEACHER-FACILITATED PROGRAM

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There are ongoing discussions about the best way to teach science to young children during the preschool and early elementary school years (Bell & Gilbert, 1996). What best practice is most likely to contribute to children's development and learning is the question that parents, teachers, and the research communities want answered. We know that young children's thinking is expanded through their development as well as their personal experiences. Children must explore, ask questions, and revise their thinking to accommodate new ideas (Mundry & Loucks-Horsley, 1999).

The purpose of this article is to discuss a model that fosters science learning through a systematic approach of understanding language at increasing higher levels of abstraction using questioning skills to elicit factual and application information. Language skills are supported with hands-on visually engaging materials for learning about life, earth and physical science during the primary grades. At the Mid- Atlantic Laboratory for Student Success headquartered at Temple University Center for Research in Human Development and Education, science educators and speech-language specialists have developed a science curriculum that promotes the content and process for learning about science as it pertains to events that young children can experience and understand.

Instructional Methods

Trends in early childhood programs have incorporated explicit teacher- led activities where the students follow the teacher's directives or exploratory, teacher- facilitated activities where students guide instruction based on their interests and curiosity (Fradd & Lee, 1999). These two different practices stem from different theories and philosophies of how young children learn and the role the adults play in the learning process. Explicit curriculum models for preschool are based upon behavioral learning principles. This theory is linked to learning theories in which cognitive competence is assumed to be transmitted through the process of repetition and reinforcement (Stipek & Byler, 1997). The explicit models use a highly structured teaching approach for acquiring academic skills. The skills emphasized tend to be those assessed by general intelligence and achievement tests. Teachers may lead small groups of children in structured question and answer lessons and drills. Teachers also spend much time correcting errors to keep children from learning incorrect answers. Workbooks and paper/pencil-oriented activities are generally included in the learning process (Schweinhart & Weikert 1997).

More current thinking incorporates the exploratory model of learning and suggests that children construct their knowledge by confronting and solving problems through direct experience and use of manipulative objects (Stipek & Byler, 1997). The goal of the exploratory teaching model is to create an environment in which children may explore, learn, and develop when involved with naturally interesting materials and events. In such a setting, there are no structured responses. Rather, activities lend themselves to creativity and exploration (Stipek & Byler, 1997). In exploratory models, the teacher's role is to serve as a facilitator for the children by providing them with the opportunities to engage in activities and

interact with their peers. Teachers who are unfamiliar with the 'facilitator role' may be uncomfortable and feel as if they are not teaching according to the curriculum.

There have been long-term and short-term studies looking at the different outcomes of these two different approaches toward early childhood education with their impact on cognitive development and social-emotional development (Becker, W. & Gersten, 1982; DeVries, 1991; Gersten, R., 1986; Schweinhart L.J. & Eikart, D.P. 1997).

Some researchers believe the explicit-directed type of teaching is management driven. Cuban (1993) says (as cited in Goldstein, 1997) "The basic imperative of elementary schooling is to manage large numbers of students who are forced to attend school and absorb certain knowledge in an orderly fashion." Cuban (1993) explains that this demand has led to the development of a curriculum approach that is linked directly to the challenge of managing children. Other researchers believe this type of curriculum is superior to exploratory, child-centered models, especially for children of low- income families. Delpit (1995) maintains that the explicit-directed type of curriculum values basic skills over creative thinking and is necessary because of the value society places on highly structured skills oriented programs. Schweinhart and Weikart (1998) state that explicit, teacher-directed instruction may lead to a temporary improvement in academic performance at the cost of missed opportunities for long-term growth in personal and social behavior. They further support the use of an exploratory, child-centered curriculum to further develop social responsibility and enhance interpersonal skills. Additional research reports that children in exploratory child-centered programs display better language development and verbal skills (Dunn & Kontos, 1997).

Both approaches have value in educating young children. Some of the issues that have been raised include, which is better for the teacher, which is better for children in developing

cognitive competence, and what curriculum models are best for developing the social-emotional development of young children. We know that students can benefit from both the explicit and exploratory. "Instead of viewing these approaches as opposing camps, they could be conceptualized as complimentary opportunities for teachers to move between perspectives," (Fradd & Lee, 1999, p.16).

One of the goals of this document is to provide an example of an effective program for developing science knowledge and language skills with young children, that incorporates both explicit-teacher directed and exploratory-child facilitated methods.

Head Start on Science and Communication (HSSC) is the early science program that has been implemented in classrooms that use the Adaptive Learning Environment Model (ALEM) (Wang, 1992), a cornerstone of the Community For Learning (CFL) comprehensive school reform model. This instructional program provides the infrastructure for blending exploratory and explicit learning to support children's unique abilities and individual differences. The program has been highly influenced by over two decades of research and broad, field-based implementation of innovative school programs (Wang, Haertel, & Walberg, 1993, 1998). CFL "draws itself from the field-based implementation of an innovative instructional program that focuses on school organization and instructional delivery in ways that are responsive to the development and learning needs of the individual child, the research base on fostering educational resilience of children and the youth beset by multiple co-occurring risks, and the forging of functional connections among school, family, and community resources in coordinated ways to significantly improve the capacity for the development and education of children and youth" (Wang, 1998, p. 10).

Developmentally Appropriate Practices

In connection with the instructional model, the National Association for the Education of Young Children (NAEYC) recommends that developmentally appropriate practices be adopted. Developmentally appropriate practices (DAP) are not curriculum, however, they provide standards encompassing high quality early childhood education programs. DAP emphasizes the treatment of children as individuals with the ability to make choices about their educational experience (Bredekamp & Copple, 1997).

The HSSC Program has included NAEYC's suggestions to implement in the classroom to meet children's individual needs. These include but are not limited to: (1) ensuring that classrooms function as caring communities so they can help children learn how to establish positive and constructive relationships with adults and other children; (2) providing opportunities for the children to accomplish meaningful tasks and experiences in which they can succeed most of the time; and (3) preparing a learning environment that fosters children's initiative, active exploration of materials, and sustained engagement with other children, adults and activities. Further recommendations include planning a variety of concrete learning experiences which are relevant to children and providing opportunities for children to plan and make choices about their own activities from a variety of learning centers.

Appropriate opportunities for learning are further supported by providing an environment that cultivates receptive and expressive language and cognitive development. As preschoolers proceed through stages of language development and cognitive growth, they gain skills in vocabulary, understanding simple stories, following directions of increasing complexity and learning about causal relations. Their expressive skills expand to use grammatically appropriate sentences and they learn to exchange ideas in discussion, discuss

why something happened, ask questions related to a topic and retell a simple story by kindergarten age. As children expand their vocabulary begin to differentiate likeness and differences, they match, discriminate and categorize objects and events through paired comparisons. Such emergent skills are precursors to later reading and writing. As young children gradually refine their visual perception and explore their environment, they learn to sequence events in logical order. They begin to make associations and can compare objects on the basis of different attributes. These abilities lead to higher level skills of planning, making judgments, and problem solving. Throughout this time, children learn that their communication has an effect on others and on their own ability to get what they want (McLean, J. & Snyder-McLean, 1999).

Classroom Dynamics

Classroom dynamics support language and cognitive development. The manner in which the teacher structures learning opportunities and the methods used to foster interaction among students while learning are critical features. Howes & Phillipsen (1998), in their study on the effects of preschool interaction, found that low levels of child-teacher closeness at 4 years old lead to social withdrawal in second grade and that pro-social ratings in second grade were best predicted by preschool classrooms that were high in time spend with peers interacting. This finding further supports the recommendation of NAEYC that teachers serve as facilitators to children's self-initiated activities, allowing opportunities to interact with children who are requesting adult support while allowing the children time to interact and work together to explore and learn. Teachers should not only provide instruction but also provide opportunities for children to explore concrete materials and interact with peers (Bredekamp &

Copple, 1997). Teachers can circulate around the room either responding to students' requests, giving individual instruction, or offering feedback and reinforcement (Wang, 1992).

Students' internal motivation to succeed is further fostered by a cooperative classroom environment. In cooperative classrooms students tend to be less focused on how smart they are relative to other students. They tend to be more focused on learning for its own sake. According to Nicholls (1990) students in cooperative classrooms focus more on how to accomplish the task and they view mistakes as a process towards learning. "Depending on the type of classroom structure teachers choose, they are communicating a view of success or failure to their students that can have a critical impact on children's beliefs." (Bempechat, 2000, p. 12).

A Best Practice Model. In deciding how to encourage students to explore the nature and meaning of science while developing their comprehension and expression, science educators and language development specialists have developed a curriculum that is both explicit and exploratory in nature, taking the best qualities of each and based it on the (1) American Association for the Advancement of Science Project 2061 Science Benchmarks, (2) Developmentally Appropriate Practices, and (3) language skills for classroom communication (Farber & Klein, 1999).

The developers of the HSSC have based their thinking on a few guiding principles. Young children have a natural tendency to explore. Children's daily playtime activities engage them in "science". Science education in school unites cognitive development and children's prior knowledge and experience with intuitive scientific theories to formulate new ideas. As they develop explanations about the world around them, they are learning broad scientific concepts. While they are discovering their world, they are questioning and investigating.

Rather than looking at the isolated science concepts, science for the early childhood student is an introduction to the "big picture". Newer approaches also emphasize learning that maximizes students' individual competencies. Using an interactive process to enhance students' questioning abilities (Stone, 1994), the HSSC Program encourages social interaction, discourse and questioning during science lessons. This interactive, analytic approach intend to increase planning and problem solving skills for kindergarten children. Students are taught to view the world in a continuous process of changing ideas. They are asked to describe and communicate those ideas as they make sense of their own learning, drawing from prior knowledge and asking questions to acquire information. This interactive inquiry-based perspective is supported by the National Science Education Standards (NRC, 1996).

Program Description

In order to foster science literacy development, the Head Start on Science and Communication Program (HSSC) was initially conceived to unite parents and teachers to promote current and future success in science for children in preschool, kindergarten, and first grade. HSSC emphasizes the development of children's language skills through an explicit teacher-directed and exploratory child-centered approach to acquiring science knowledge. The program aims to achieve three very specific goals:

- broadening participants' science knowledge and conceptions around three science domains: life science, earth science, and physical science;
- enhancing age appropriate abilities through scientific inquiry for observing, hypothesizing, predicting, investigating, interpreting, and drawing conclusions; and
- integrating science with communication to recall, identify change, generalize, analyze, judge, and problem solving information.

The two phases of the HSSC Program are described below. Phase I included outreach and planning with parents and teachers in the community and phase II was an instructional scaling-up attempt to incorporate specific science experiments with students in classrooms.

Phase I

The participants in phase I of the study represented Head Start programs from 18 schools throughout Philadelphia and New Jersey. Participants included 18 teachers, 11 classroom assistants, and 10 parents ranging from 19 to 53 years of age, and including three ethnic groups: African-American (68%), Caucasian (29%), and Latino (3%). Eighty-five percent of the Head Start programs represented were based in large urban settings, 15% in suburban or rural settings. While the educational background of participants varied, none of the participating parents held college degrees.

All participants received interactive inquiry-based training on broadening their general science knowledge in topics of life, earth, and physical science, and creating strategies to establish learning environments that encourage an inquiry approach to everyday learning in school and at home. A basic design principle of the HSSC program is the inclusion of parents in the learning process. This was a critical element to the success of the planning phase.

Program Components

Phase I of the HSSC program included three components: (1) a summer institute that provided intensive, hands-on instruction and learning experiences for participants; (2) ongoing follow-up technical assistance and training support for program implementation; and (3) extending the implementation of the HSSC program in the first cohort of participants to

community-based science rich centers such as area museums, as well as moving into phase II of the program.

The focus of the two-week summer training program was to provide professional development and an opportunity to promote collaboration among teachers and parents for greater problem solving skills. The primary goal of the summer institute was to create a lifelong interest in science for participants and the children with whom they interact. In keeping with the intent of the National Science Education Standards, the HSSC curriculum materials were developed to assist participants in fostering their own and the children's "natural curiosity" to learn about the world.

The curriculum materials and experiments were designed to promote inquiry-based hands-on science as a vehicle for language development with young children. Each experiment begins with background information about the topic under investigation and a teacher demonstration module providing an opportunity for teachers to engage students with manipulate materials and ask guided questions to gain more information about what students know and what they need to learn. As the project participants implemented these plans that were developed during the summer, the technical support became increasingly site-specific based on individual classroom needs. For example, one teacher expressed the need to learn about various inferential questioning techniques while another teacher requested strategies for student collaboration.

Method of Data Collection

Data on program implementation was obtained through surveys, on-site observations, and interviews. Participants (teachers, teaching assistants and parents) were rated as either "encouraging inquiry" for which questions were asked of students to help them gain needed

information to solve problems or "give-away" for which the questions asked by students were immediately answered by an adult. In addition, on-site observations were conducted to determine each classroom's primary mode of interaction. Classrooms were as being "collaborative" or "competitive".. The post-implementation surveys were followed by semi-structured, open-ended interviews to learn more about classroom interaction.

Phase I Findings. Changes in Questioning Strategies- Preliminary findings from the post-implementation surveys indicated that 50% of the teachers relied solely on the use of questioning to encourage problem solving with the students, 33% encouraged problem solving as well as giving away the answers, and 17% tended to simply 'give away' answers as opposed to using questions to get children to try to solve the problems themselves. The majority of parents (83%) indicated that they engaged in both questioning to encourage problem solving as well as giving away answers, while almost half of the classroom assistants reported that they tend to give away answers. In summary, classroom assistants gave away substantially more answers to students when compared to teachers and parents, who encouraged more problem-solving through questioning.

*Changes in Classroom Interaction-*A teacher's philosophy and his or her interaction with students has been found to have a major impact on how students view success and failure. Nicholls (1990) has shown that traditional, competitive classrooms produce children who are overly concerned with how they are doing relative to their peers. This competitive style makes children anxious about mistakes and they tend to equate their mistakes with failure. This has been found to impact on children's beliefs about themselves and their ability. Conversely, cooperative classrooms foster a sense of learning through accepting mistakes as experiences for growth. Nicholls further points out that the challenge for teachers is to help students

maintain a healthy balance among accepting mistakes as opportunities to learn, believing they have the ability to learn and knowing that effort will help them maximize that ability. Prior to training, the 12 observed classrooms lacked collaborative interaction among teachers and students. Following the training (spring, 1997), the dynamics of the classrooms were observed to determine if there was a change in their primary mode of interaction. Eight of the twelve classrooms were rated as collaborative, engaging in small group problem-solving teams with verbal interactions among teachers and students. Teachers not only asked questions of students but also encouraged students to ask questions for clarification, and to understand that learning takes time and that mistakes are accepted when followed up with new information to solve problems. Three classes were found to be both collaborative and competitive, fluctuating in interactions during the course of the day. Only one class remained predominately competitive in nature. Collaborative interactions included working together on projects with students assuming varied and complementary roles as they worked on problem-solving activities in science. Classroom characteristics included listening, waiting, acknowledging comments, inviting questions, accepting others' points of view, and encouraging students to express ideas. Competitive interactions included activities that focused on performance with a form of grading attached.

Changes in Classroom Focus. When interviewed after program implementation, participants indicated that they changed their classroom focus to primarily inquiry-based (75% of classes). The participants said they used more open-ended questions with their students instead of asking yes-no type questions. They asked wh-type questions (who, what, where, when, why, and how) with much greater frequency (encouraging recall, application and

problem solving). Some teachers set up science centers and other exploratory learning centers within the classroom setting.

Generally, parent involvement reinforced classroom learning. Teachers sent letters to parents explaining what would be discussed in class and encouraged parents to visit the classroom. Teachers and assistants discovered that the use of language targeting vocabulary development and questions was integral to enhance learning and engagement of young children. Teachers reported making a difference in the children's scope of cause-effect knowledge.

At the completion of phase I, participants had many ideas for the future of the HSSC program. Some teachers planned to engage other faculty members in the brainstorming questions that tapped inferential thinking for science experiments. Other teachers looked forward to involving more parents, noting that parental involvement is one key to success of program implementation. Overall, participants anticipated implementing the techniques and using the ideas they learned. Because of the success of phase I, the program was expanded from preschool children to those in the early elementary years (K-2). Phase II of the program will include further implementation, refinement of program materials, and expansion to K-2 classrooms.

Phase II

Phase II of HSSC has involved the formal development of 30 science experiments and a manual covering three science domains (see appendix A); life science, earth science, and physical science. The experiments are based on benchmarks written by the National Science Foundation (National Research Council, 1996). Using specific language concepts and scientific background information, the teacher initially tests students individually using the pretest to

assess the knowledge base. Following the pretest, the teacher introduces each science experiment to a small group of students or to the entire class. Students also have an opportunity to engage in exploration using the manipulatives and directions within science activity kits. After the experiment has been completed, the post-test is administered to assess content knowledge gains.

The HSSC early childhood science program encourages children's natural inclination to explore by providing an early learning environment that is conducive to science literacy. The HSSC program incorporates the use of individualized hands-on science learning activity boxes as well as small group and whole class instruction. Providing hands-on learning experiences fosters curiosity in young children and engages them in the social and cognitive processes that promote language and communication skills essential to continued academic success. The combination of explicit teacher-directed and exploratory child-centered methods allows young children to gain information, explore their surroundings, and develop meaning, thus honing their communication and problem solving skills.

The explicit role of the teacher is an important component to this early childhood program. As a facilitator, the teacher assists individual students toward gaining new scientific knowledge, by relating experiences and answering personal questions when appropriate. Initially, teachers facilitate the demonstration lesson that introduces the scientific concepts embedded in the students individualized activities. The classroom teacher provides background information and supports students as they learn newly introduced science material. Manipulative materials and supplies for the science activities are all included in 150 individually boxed learning activity kits.

After each science demonstration, the teacher asks probe questions to determine general concept understanding. Based on the lesson taught during the science demonstration, the students will have the opportunity to use their knowledge to work through a series of five-leveled science activities. The science activities are arranged hierarchically in cognitive levels from basic matching tasks to higher level associations based on understanding relationships.

The first level in the hierarchical structure of the program is *matching*. While the students work on the first science activity, they are encouraged to identify likeness among objects. This is followed by level 2, a *discrimination* task. This level focuses on the student's ability to not only identify similarities but to also distinguish differences. These activities help foster the ability to compare and contrast, a basic scientific process (Hammrich, 1998). Level 3 focuses on *categorization*. Children use their ability to discover similarities and organize information into like units. Level 4 requires the ability to order information for *sequencing*. Students arrange various items according to patterns or gradations noting specific stages and order. The final level 5 involves an *association* activity. These activities incorporate previous knowledge levels and challenge students to transfer information, understand relationships, and make new connections.

To demonstrate understanding of scientific concepts, students answer six post-experiment questions that directly relate to the five activity levels. The post-assessment questions are based on a modified taxonomy derived from Bloom (Bloom, 1984). To determine if children have acquired knowledge from engaging in the experiments, students must initially *recall* factual information.. This type of question draws on the student's knowledge of previously introduced information. The table below provides a brief look at the six questioning levels that tap increasingly more demanding cognitive abilities.

Table 1

Six Levels of Post-Experiment Assessment Questions (read down)

RECALL ↓ **facts**	**CHANGE** ↓ **added information**	**GENERALIZE** ↓ **units of thought**	**ANALYZE** ↓ **think it through**	**JUDGE** ↓ **speculate**	**PROBLEM SOLVE** ↓ **apply to new situations**
Tell what...	Tell what X means	Describe how X is used in example	Tell how X & Y are alike or different	Explain why X is better or worse than Y	Explain how you could make it better
Tell when...	Tell why (reason or purpose)	Tell what is an example of...	Explain why you think X did Y	Tell why you agree or disagree	Explain what you plan to do
Tell where...	Tell how X felt	Tell why it happened	Tell what is true/not true	Describe which you choose first/last	Explain what you think will happen next
Tell who or whose...		Explain what can be done	Tell what you learned	Explain what you think will happen	Describe a new thing that can be done
Tell which...					Describe what you can create
Tell how...					Describe how you would do X
Tell how many...					

Program Results

The Head Start on Science & Communication (HSSC) Program was implemented in five large urban public school first grade classrooms in Washington, DC and Trenton, NJ during the 1999-2000 school year. There were a total of 101 children in the sample population. Of these students, 98 participated in the pretest (53 females, 45 males) and 85 of those children participated in the posttest (44 females, 41 males). The ages of these students ranged from 7 to 8 years old with a racial composition of 87% African American and 13% Hispanic. Results of the HSSC Program were derived from (1) student performance on the 'Unit Pre-Post

Tests for Life, Earth, and Physical Sciences' and (2) degree of implementation and classroom processes derived from classroom observations.

Twelve experiments are discussed in this section on program results. Due to the late start of the program within the school year, not all 30 experiments could be completed by teachers and students. Generally, one demonstration experiment with follow-up activities is conducted weekly. Table 2 indicates the breakdown of students participating in phase II of the program.

Table 2

Students completing experiments for testing

	Girls	**Boys**
Pre test	53	45
Post test	44	41

The science and language concepts for each of the twelve experiments of life, earth and physical science include:

- Changing Fish – change, adaptation, and variations among fish and their environments
- Coloring Celery – levels of water and absorption for plants
- Evaporating Liquids – wet, dry, and moisture associated with events
- Blowing Across – movement, distance, air, and wind
- Gathering Nature – plant and animal features for comparison and classification
- Finding Earth – varieties of environmental surfaces
- Growing Seeds – patterns, similarities and differences in growth
- Making Plants – parts and wholes of plants and their functions
- Moistening Seeds – sunlight, moisture, and development of the seed

- Organizing Rocks – grouping characteristics and textures
- Bouncing High – height, movement, and force
- Bubbling Air – space, observation, and size

Implementation of the HSSC Program

The first grade teachers in this study were chosen by the school principals after indicating an interest in participating in a science program. The first grade teachers in the experimental condition followed the HSSC Program, providing standards-based curriculum with learning activity boxes for life, earth, and physical sciences. In addition, these teachers received technical support in their classrooms from an implementation specialist on an average schedule of two times per month. During the fall of 1999 fourteen first grade teachers in the targeted schools were observed to determine degree of implementation on the twelve critical dimensions of the Adaptive Learning Environments Program (ALEM) of the Community For Learning Comprehensive School Reform Model (CFL) by Margaret C. Wang (1992). Degree of implementation scores are reflected in percent form referring to the number of dimensions met within each category. The 12 areas for degree of implementation include: (1) arranging space and facilities; (2) creating and maintaining instructional materials; (3) establishing communication and refining rules and procedures; (4) coordinating and managing support services and extra personnel resources; (5) record keeping; (6) diagnostic testing; (7) prescribing; (8) monitoring and diagnosing; (9) interactive teaching; (10) instructing; (11) motivating; and (12) developing student self-responsibility. An average score for all 12 areas is referred to as the DOI composite. Results indicate that in the fall, the average degree of implementation (DOI) composite for the four experimental classroom teachers was 67.30 and the average DOI composite for the ten control classroom teachers was 81.44. In the spring,

following implementation of the HSSC Program, the average DOI composite for the experimental group increased to 87.50 whereas the control group DOI composite remained steady at 81.73.

Table 3

Overall degree of implementation changes among groups.

GROUP	***Experimental Fall 1999***	***Experimental Spring 2000***	***Control Fall 1999***	***Control Spring 2000***
NUMBER CLASSES	4	5	10	12
MEAN	67.30 (25.16)	87.50 (11.99)	81.44 (18.53)	81.73 (25.19)
CHANGE	-	+20.20	-	+0.29

Results indicate that teachers from the experimental classes increased degree of program implementation by approximately 20% whereas the control classroom teachers made negligible change. Although the experimental teachers started out lower in degree of implementation they achieved higher scores by the end of the school year for arranging space/facilities, establishing/communicating rules, coordinating/managing support, record keeping, diagnostic testing, prescribing, monitoring/diagnosing, interactive teaching, instructing, and motivating students than did the control classroom teachers. The final two assessed areas, creating / maintaining instructional materials, and developing student self-responsibility were similar in degree of implementation scores (less than one point difference) between the two groups by the end of the school year.

Program Gains

The areas that indicated a gain in degree of implementation from fall to spring for teachers with experimental classes included: arranging space and facilities (8%), creating and maintaining instructional materials (40%), establishing and communicating rules (20%),

coordinating and managing support (30%), record keeping (50%), prescribing (40%), monitoring and diagnosing (25%), interactive teaching (30%), instructing (17%), motivating students (15%), and developing student's self responsibility (4%). In the control classes the following percent increases were noted: creating and maintaining instructional materials (4%), establishing and communicating rules (7%), record keeping (10%), prescribing (7%), monitoring and diagnosing (1%), interactive teaching (14%), and developing student's self responsibility (6%). Experimental classrooms made superior gains when compared to control classrooms in eleven of twelve DOI areas assessed.

Curriculum-Based Pre-Post Test Results. The 'Unit Pre-Post Tests for Life, Earth and Physical Sciences' (Hammrich & Klein, 2000) were administered to first grade children in five classes to determine growth in content knowledge. There were two questions asked for each experiment prior to and following program instruction. The first question for each experiment, labeled 'A', was 'factual' and based on factual recall of information. The second question for each experiment, labeled 'B', was 'application' and based on students' explanation of information. For each question, students received a score of '0' indicating an incorrect response or a score of '1' indicating a correct response. All pretests and post- tests were administered individually to students by the classroom teachers with the support of program staff during pretest time. Table 3 provides a breakdown of scores for each type of question (A and B) for the twelve completed experiments.

Table 4
Gains from pre-to-post test scores for science content knowledge with twelve experiments.

Experiment Name	Number of Students	Mean Pretest Score	Mean Posttest Score	Gain
Changing Fish – A	56	.38	1.00	.62
Changing Fish – B	56	.00	.91	.91
Coloring Celery–A	31	.35	.91	.55
Coloring Celery-B	31	.45	.97	.52
Evaporating Liquid-A	12	.17	.92	.75
Evaporating Liquid-B	12	.00	.92	.92
Blowing Across-A	17	.71	1.00	.29
Blowing Across-B	17	.59	1.00	.41
Gathering Nature-A	37	.43	1.00	.57
Gathering Nature-B	37	.00	1.00	1.00
Finding Earth-A	47	.70	1.00	.30
Finding Earth-B	47	.66	.96	.30
Growing Seeds-A	20	1.00	1.00	.00
Growing Seeds-B	20	.00	1.00	1.00
Making Plants-A	20	.20	1.00	.80
Making Plants-B	20	.00	1.00	1.00
Moistening Seeds-A	20	.10	.80	.70
Moistening Seeds-B	20	.00	.55	.55
Organizing Rocks-A	32	.34	.94	.60
Organizing Rocks-B	32	.00	.81	.81
Bouncing High-A	11	.64	1.00	.36
Bouncing High-B	11	.00	1.00	1.00
Bubbling Air-A	12	.50	.92	.42
Bubbling Air-B	12	.33	1.00	.67

Results indicate that there was a significant difference between pretest and post-test knowledge beyond the $p<.05$ level for all experiments tested. Students in the HSSC Program made significant gains in content knowledge at both factual and application levels.

Gender Differences

There were a total of 53 female first graders and 45 male first graders who took the pretest. Students engaged in self-paced investigations (child-initiated) to complete the five levels of each experiment following teacher demonstrations (teacher-facilitated). Post testing took place when the student completed the entire experiment. Table 4 indicates that girls generally scored lower than the boys at pretest time. In fact, there were only two experiments (#6- finding earth and #9-moistening seeds) in which they scored higher than the boys initially. However, post-test results revealed that the girls matched the boys on factually based questions for seven of the twelve completed experiments and surpassed the boys on one experiment (#10 – organizing rocks).

Table 5

Factual pre-post test question means for girls and boys.

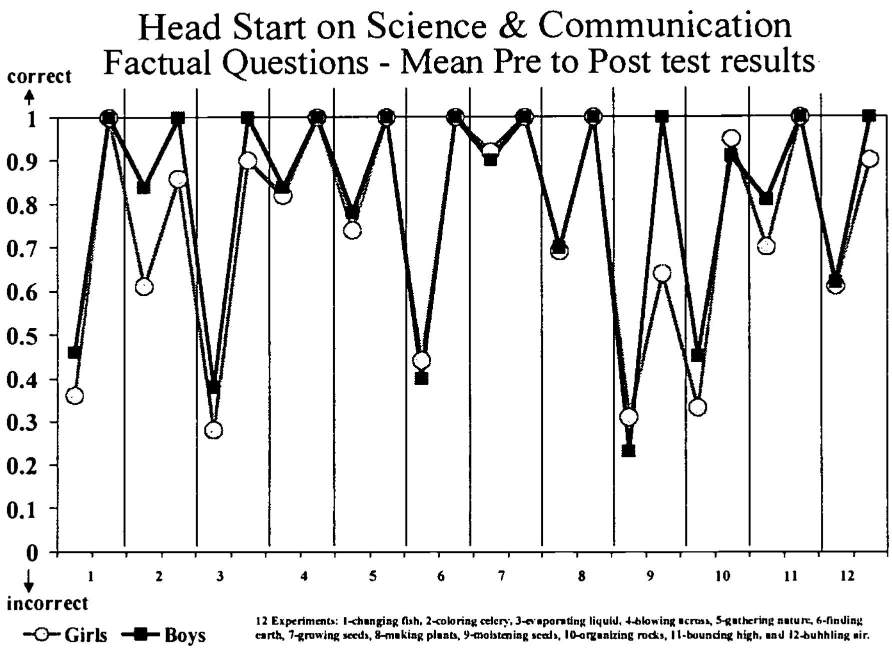

Table 6 below compares girls and boys on application-type questions requiring higher level reasoning and knowledge about science content. Girls scored lower than the boys for half (six of twelve) of the experiments at pretest time, considerably better than they performed on the 'factual' questions reported in table 4. This could lead one to believe that girls have a stronger ability to make associations and explain information than they do on basic recall of science facts. This finding was recorded prior to any formal instruction with the Head Start on Science & Communication Program. After instruction and exploration using the program, post-test results revealed that the girls matched the boys on 'application' questions for eight of the twelve completed experiments and surpassed the boys on one experiment (#1 – changing fish).

Table 6.

Application pre-post test question means for girls and boys.

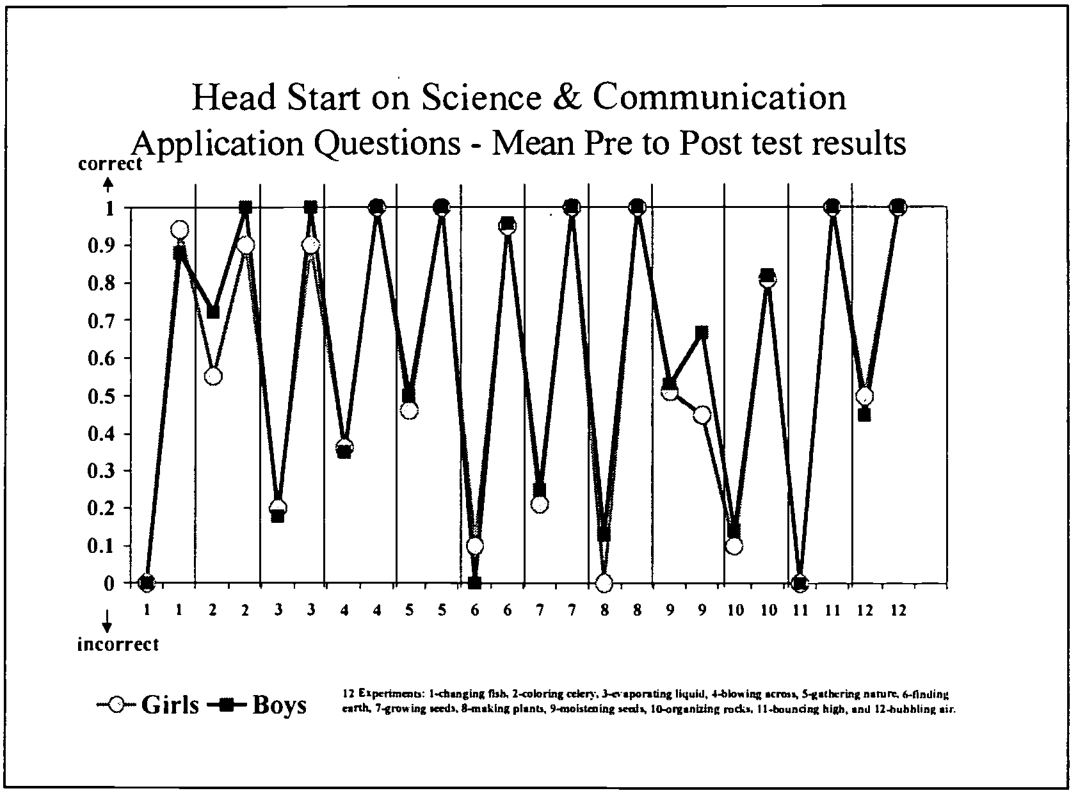

Table 7 indicates that although the girls in the study scored slightly lower than the boys on both factual and application questions at pretest time, their scores approximated the boys at post-test time with both girls and boys evidencing mastery of the material.

Summary Of Head Start On Science & Communication Results

Results indicated that the Head Start on Science & Communication Program (HSSC) had positive achievement effects for students in the program. Overall, there was a significant difference between pretest and posttest knowledge beyond the $p<.05$ level for all twelve completed experiments. Gains ranged from a low of 0.00 (an incorrect score) to a high of 1.00 (a correct score). The summary charts below reveals significant pre-post test changes beyond the $p<.05$ level of significance.

Table 7

Mean pre-post test scores for factual questions

	Factual – Pre test means	**Factual - Post test means**
Girls	.567 (n=53)	.937* (n=44)
Boys	.610 (n=45)	.992* (n=41)

* Significance beyond p<.05

Table 8

Mean pre-post test scores for application questions

	Application – Pre test means	**Application – Post test means**
Girls	.092 (n=53)	.912* (n=44)
Boys	.270 (n=45)	.944* (n=41)

* Significance beyond p<.05

Teachers reported benefits in their methods to instruction and classroom management after using HSSC. Results indicated that in the fall, the average degree of implementation (DOI) composite for the four HSSC experimental classroom teachers was 67.30 and the average DOI composite for the ten control classroom teachers was 81.44. In the spring,

following the HSSC Program, the average DOI composite for the experimental group increased to 87.50 whereas the control group DOI composite remained steady at 81.73.

The Head Start on Science & Communication Program significantly benefited teachers in: (1) arranging space and facilities; (2) establishing communication and refining rules and procedures; (3) coordinating and managing support services and extra personnel resources; (4) record keeping; (5) diagnostic testing; (6) prescribing instructional material; (7) monitoring and diagnosing individual needs; (8) interactive teaching; (9) instructing; and (10) motivating students. Students benefited in their comprehension of language and level of knowledge acquired as evidenced by the gains they made when answering both 'factual' and 'application' types of science questions previously unknown.

Conclusion

Gaining knowledge about scientific processes and principles while increasing cognitive, linguistic, and literacy skills is a challenging and important task. Whether information is acquired through explicit, teacher-directed methods or through exploratory, child-centered methods, it cannot be assumed that one method of learning is better than the other, or that one should one replace the other. Not all children learn in the same way and they may not learn equally well using only one method. Often, we find that it is best to combine more than one method to help children learn to their maximum potential. In efforts to motivate children to explore, understand, analyze, and create, teachers are encouraged to combine both explicit and exploratory teaching methods. This way students are given basic information from which to begin and to peak their curiosity for continued exploration. The Head Start on Science and Communication Program unites language development and science inquiry with a

multifaceted curriculum to meet the needs of teachers and children within our diverse educational arena of the 21st century.

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Appendix A

Science Activity Index

Life Science

1. Listening Inside *Things that make sounds vibrate.*
2. Guessing Boxes *Using your senses, you can describe physical properties of different objects.*
3. Coloring Celery *Water can be absorbed.*
4. Pouring Shapes *You can change some materials' properties but not all materials respond the*
   same way.
5. Melting Materials *Water can change back and forth from a liquid to a solid and from a liquid to a gas.*
6. Feeling Water *Using your senses you can feel temperature for variations from hot to cold.*
7. Evaporating Liquids *Water and moisture can disappear if left in an open container.*
8. Changing Fish *Animals have external features that help them adapt and survive.*
9. Ordering Nuts *You can describe and organize objects by their physical properties.*
10. Sensing It *You can use your senses to identify properties of objects.*

Physical Science

11. Bouncing High *You can vary movement of something by force.*
12. Falling Objects *You can change the position of something by pushing it.*
13. Sticking Objects *Magnets can make some materials move.*
14. Spilling Over *Things can be done to change a material's proper*ties.
15. Bubbling Air *Most living things need air.*
16. Floating Food *Some objects can float, while other objects sink.*
17. Creating Pitch *Sounds can be low or high in pitch.*
18. Coloring Line *You can change colors by adding other colors to them.*
19. Measuring Sound *You can use your senses to hear different sounds.*
20. Moving Hands *You can create heat from friction.*

Earth Science

21. Finding Earth *Different surfaces have different textures.*
22. Making Plants *Plants are comprised of various parts that have different functions.*
23. Blowing Across *Force of air can make objects move various distances.*
24. Organizing Rocks *Rocks come in different sizes, shapes, textures, and colors.*
25. Moistening Seeds *Plants need water and light to grow.*
26. Running Liquids *Physical properties can be changed.*
27. Growing Seeds *Plants share similarities and differences in features and growth.*
28. Sinking Boats *Buoyancy and weight are factors in flotation..*
29. Gathering Nature *Materials in nature have similarities and differences.*
30. Observing Objects *Some objects' physical properties can be changed and others cannot.*

EXAMINING DISCOURSE IN ELEMENTARY SCIENCE METHODS: DIFFERENCES BETWEEN SCIENCE CONTENT AND PEDAGOGY

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The development of a scientifically literate society is dependent on effective communication. Accordingly, the Benchmarks for Science Literacy (the Benchmarks) (American Association for the Advancement of Science [AAAS], 1993), which defines science literacy goals for students K-12, contains an entire section on communication skills. One of the skills described in the Benchmarks is that "students should be able to participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarifications or elaboration, and expressing alternative positions" (p. 297). The ability of students to achieve this goal is dependent on a teacher's ability to incorporate such opportunities into lessons. Moreover, the National Science Education Standards (National Research Council [NRC], 1996, 2000) state the importance of learning to teach through inquiry. As part of learning through inquiry, teachers need the experience of "proposing answers, explanations, and predictions; and communicating the results" (NRC, 1996, p. 23), often accomplished via classroom discourse. Additionally, classroom discourse is necessary for teachers to determine what the students understand and misunderstand, what they are thinking, and what they are learning (NRC, 2000).

We believe that a teacher preparation program must therefore model and teach how to facilitate high quality classroom discussion. To do so, science methods instructors must examine and understand their own roles, intents, and actions during classroom discussions. Thus, one of

the first steps in improving our preparation of teachers' skills in leading discussions is to understand science classroom discourse as it occurs in science teacher education courses.

Literature Review

Classroom discourse, often in the form of small and large group discussion, can be dialogic or monologic in nature (Nystrand, 1997). Dialogic discussions contain statements that "respond to previous utterances at the same time they anticipate future responses" (p. 8). Such discourse is "structured by tension…as one voice 'refracts' another" (p.8). Bakhtin (in Todorov, 1984) required the dialogical semantic relationship to be structured by "two verbal works, two utterances, in juxtaposition" (pp. 60-61). The utterances must express the authors of the utterances and thus establish two-voiced discourse.

In contrast, during monologic discussions teachers "'prescript' both the questions they ask and the answers they accept, as well as the order in which they ask the questions" (Nystrand, 1997, p. 12). Teachers thwart dialogue by evaluating student responses instead of responding to ideas. Lemke (1990) and others have referred to this discourse genre as Triadic Dialogue or QAE (question, answer, evaluation). In Bakhtinian terms, "there is no second voice alongside that of the author" (in Todorov, p. 63); others' utterances are framed within the "voice" of the original author creating a singular context and a singular semantic orientation.

Discourse also maintains two distinct functions: generating meaning and conveying meaning. Mortimer and Machado (2000) referred to these functions as generative (or persuasive) and authoritative, respectively. Thus, the nature and the function of the discourse can determine the extent to which classroom discussion is inquiry-based, which is a critical characteristic of science education (NRC, 1996, 2000). "The discussion leader must find a way to teach that is neither too dominant nor too reserved" (Brookfield & Preskill, 1999, p. 194).

Teachers need to model how to challenge, clarify, and elaborate ideas; yet, they need to "allow the children to take more control of what is said, when it is said, and how it is said" (Bloom, 2000, p. 90). For this to occur, teachers need to help students understand the nature and functions of classroom talk (Bloom).

Researchers examining discourse in the science classroom, regardless of education level, have rarely focused on teacher roles and intents with regards to discourse type, monologic and/or dialogic. Elementary (Varelas & Pineda, 1999), middle (Varelas, 1996), and high school (van Zee & Minstrell, 1997) studies have examined student conceptual understanding based on classroom discourse. However, nature of discourse and the roles and intents of the teacher in guiding the discourse have been virtually ignored. Studies that have researched the teacher's role in science classroom discourse included examinations of wait time (Tobin, 1984) or questioning techniques (van Zee & Minstrell, 1997) to engage students in more reflective thinking. Both of these studies limited the discourse examined to QAE and did not examine the multiple roles of the instructors or their multiple intents in using discourse. Shepardson (1996) discussed how an elementary teacher mediated student learning through social interactions that negotiated student status, action, and meaning. While the study focused on the students, this research did to some degree address the teacher's roles in social interactions and discourse, but not in terms of monologic and dialogic.

Studies done at the university level with regard to classroom discourse also have done little with types of discourse. For example, Koballa (1984, 1985) examined student persuasive communication in preservice elementary teacher science classes and its influence on attitude changes toward energy conservation. While these studies looked at discourse function, they did not examine the monologic/dialogic nature of the discourse.

The necessity for our research stems from the void in the literature regarding the roles of teachers in science methods classrooms with regards to types of discourse used and their intents for the discourse. To promote inquiry-based science instruction, it is important to examine the nature of discourse in elementary classrooms during science instruction. Additionally, the need exists for the study of discourse similarities and differences when teaching science versus pedagogy within the science teacher education classes.

Research Design

This study was theoretically framed by a constructivist perspective (Schwandt, 2000). Our research was guided by the relativistic ontological assumption that realities are multiple, constructed, and holistic (Lincoln & Guba, 1985). Reality is a socially and experientially constructed entity and its form and content depend on those who hold the construction (Lincoln & Guba, 2000; Schwandt, 2000). Within the constructivist framework exists an epistemological belief that the inquirer and the object of inquiry are interactively linked, influence one another, and become inseparable (Lincoln & Guba, 1985, 2000). Additionally, the methodological perspective of a constructivist paradigm is that inquiry is hermeneutical and dialectical. Investigators and participants participate in dialogue among themselves and with the data to develop "more informed and sophisticated reconstructions" (Lincoln & Guba, 2000, p. 170), interpreted using hermeneutic techniques. Because "understanding is always interpretation and hence, interpretation is an explicit form of understanding" (Gadamer, 1994, p. 307), varying constructions were compared, contrasted, and eventually understood through a dialectical interchange. The final rendering, "one interpretation among multiple interpretations of a shared or individual reality" (Charmaz, 2000, p. 523), includes the etic construction of the investigators

informed by the emic constructions of the participants and is more sophisticated than any antecedent constructions.

In accordance with the constructivist theoretical framework, we utilized an interpretive research design (Denzin & Lincoln, 2000). The design permitted flexibility "to allow for discoveries of new and unexpected empirical materials and growing sophistication" (Denzin & Lincoln, p. 368). An important aspect of our interpretive research design was self-study.

The two major purposes of teacher self-study deal with "refining, reforming, and rearticulating" education (Cole & Knowles, 1996, p. 1). The first purpose of self-study is personal professional development. Self-study of this nature aims at improving pedagogical practices. The second purpose of self-study is to enhance understanding of teacher practices, processes, and contexts. This form of self-study aims to advance knowledge about teaching and its settings. Obviously, the two purposes are not mutually exclusive, although, typically, one predominates. At a minimum, self-study requires "taking an inquiry stance towards our practice" (Raphael, 1999, p. 49). This requires developing teaching methods, practices, and curriculum, then implementing them, followed by studying them.

Paulsen and Feldman (1995) advocated using self-study to address the challenge of improving college level teaching. They concentrated on the need for faculty members to improve instruction by studying themselves and discovering how they "interact with their own environment" (Paulsen & Feldman, p. 9). Moreover, Paulsen and Feldman claimed, "the best source of informative feedback available to most instructors is themselves" (p. 9). Consequently, the advancement of university teaching requires self-study.

The self-study aspect of our design allows for a strong emic perspective and an "insider's" individual interpretation of the research. In addition to standing alone, this

perspective can weave with those of the other members of the research team. The final constructions of our individual and shared realities can only be strengthened by emic perspective gained from self-study.

Research Questions

As part of a teacher-as-researcher project and in an effort to better understand her own teaching style and efficacy, Hubbard undertook an informal self-study of her teaching during an elementary science methods class. From this initial study, she established that she used discussion techniques differently when teaching science content as compared with teaching pedagogical topics. To better define and understand these differences, Newman and Abell joined Hubbard in a formal study of her teaching practices during an elementary science methods course. We undertook a systematic inquiry of classroom discourse to examine the following research questions: How does classroom discourse in an elementary science methods course differ between teaching pedagogy and teaching science content? To what extent are pedagogy and science content taught dialogically and/or monologically in the undergraduate elementary science teaching methods course? How does the instructor account for such differences? The focus of this paper is on the first two research questions.

Research Setting and Participants

The elementary science methods course in the study is built on a reflection orientation (Abell & Bryan, 1997) that provides opportunities for students to build theories of science teaching and learning as they: (a) observe others teach, (b) reflect on their own teaching, (c) read expert theories, and (d) examine their own science learning. Students engage in both science content explorations and pedagogy activities in the class. In addition to sampling by convenience (Patton, 1990) and this being the course that Hubbard studied informally, we chose

this setting because we previously have used this course to examine several different aspects of science teacher preparation (Abell & Bryan, 1997; Abell, Bryan, & Anderson 1998; Abell, Martini, & George, in press; Abell & Smith, 1994) and thus there is a substantial knowledge base from which to work. The course section in this study was somewhat unusual in that it occurred as an intensive 8-week program during the summer with only 12 students, 9 females and 3 males. All of the students had just completed their third year in the teacher education program.

Role of the Researchers

Hubbard, the course instructor, taught elementary and middle school science for five years and had taught the methods class the previous two semesters. In addition to teaching the course, Hubbard participated in formal and informal interviews during the study.

Newman served a peripheral membership role in the course taught by Hubbard. In a peripheral membership role, researchers feel "an insider's perspective is vital to forming an accurate appraisal of human group life, so they observe and interact closely enough with members to establish an insider's identity without participating in those activities constituting the core of group membership" (Adler & Adler, 1998, p. 85). Newman taught high school science for ten years and during that time regularly aided elementary teachers with science instruction. Moreover, he spent one year as supervisor of science for a suburban school district and has taught several teacher education and science courses at the university level. Newman regularly attended class, closely observed activities, took field notes, and interviewed participants without engaging in course activities. As the project progressed, Newman maintained the stance of empathic neutrality (Patton, 1990) so as to not influence the classroom functions.

Data Collection Techniques

We used a variety of data collection techniques in this study, including peripheral membership observation, interviewing, videotaping, audiotaping, and collection of documents.

Peripheral Membership Observation

Newman visited the classroom for six of the eight weeks the class met. The other two weeks, the students participated in field experience and met to prepare lessons. When Newman was in the classroom, he observed the class and took field notes that contained, but were not limited to, descriptions of the environment, participants, activities, researcher's feelings, interpretations, and reflections.

Interviews

Weekly informal discussions were used to ascertain the teacher's plans and goals regarding science and pedagogy instruction, specifically with reference to the use of discourse. Weekly follow-up discussions addressed the teacher's feelings and attitudes about the completed lessons. After each observed class meeting, Newman interviewed Hubbard regarding her use of discourse during the lessons with specific attention to science/pedagogy and monologic/dialogic issues. We developed interview protocols and reconstructed them following the guidelines for interview guide approach and standardized open-ended interview from Patton (1990). We also conducted informal student interviews as necessary to better address our research questions.

Videotaping

Videotaping of the lessons began once Newman was established in the classroom as a peripheral member. One camera, focused on the instructor, recorded all classroom activities. Additionally, we used the videotapes to elicit teacher responses during interviews.

Audiotaping

We used three recorders during classroom observations, one for each group of students. When the class met in large group discussions, we used one recorder to supplement the field notes and videotape recording. We also recorded all post-class interviews.

Collection of Documents

We collected copies of lesson plans, relevant handouts, and student work deemed important to the study.

Data Analysis

Multiple data sources, field notes, class transcripts, and interview transcripts, were used throughout the study and allowed triangulation. Field notes and transcripts of classroom discourse were the primary data sources. Data analysis began in conjunction with data collection and continued through the write-up phase of the project. In the analysis of the discourse data, we used constant comparative methods (Glaser, 1992), reading and rereading the data and comparing segments for similarities and differences using coding which reflected the concepts each segment exemplified (Patton, 1990). This process of open coding progressed until no new concepts emerged from the data. We revisited the data once it was coded to ensure that the coding was focused to the research questions guiding the study. Each research team member independently analyzed the data. We then came together as a team and discussed patterns, offered confirming and disconfirming evidence, and generated assertions grounded in the data.

The techniques used to analyze and interpret the data are rooted in the philosophy of hermeneutics and appropriate given the theoretical frame of constructivism. The study was hermeneutical in the sense that the participants (especially Hubbard) were interpreting situations and the researchers were interpreting the teacher's interpretations to establish deeper

understanding and collective meaning (Patton, 1990). Interpretation and understanding are dialectically linked; thus, the participants' interpretations are influenced by their beliefs, values, and prior experiences. Analogously, our interpretations of the participants can be understood only in the light of our own beliefs, values, and prior experiences.

After mapping the videos and discussing the data, we established three major discourse focal points for detailed analysis: demonstrations, open-ended discussions, and class consensus discussions. For each discourse format, we selected an example in which science seemed to be the predominate content and an example in which pedagogy seemed to be the predominate content. We then transcribed the six segments and determined speaking patterns - who spoke when and how often. After establishing tentative categories for function of each utterance, we individually recoded each transcript. Each researcher developed new codes as needed, which were later added to the coding scheme. This iterative process of individually recoding and collectively interpreting the data continued throughout the study. Using patterns of speaking, functions of utterances, and vocality, individuals and then the team labeled sections of each transcript with regards to the extent the section was science and/or pedagogy and monologic and/or dialogic.

Results

Three whole-class discourse formats occurred regularly in the course, in both science content and pedagogy contexts: demonstrations, open-ended discussions to share ideas, and discussions to reach consensus. We entered the analysis assuming that the discourse patterns in these three formats would differ, and that discourse in science and pedagogy contexts would differ. Our findings were that the speaking patterns alone were insufficient tools for analyzing

the research questions; issues of function, voice, and intent became equally important in describing the discourse.

Demonstrations

The demonstration examples chosen included a pedagogical technique, interviewing students, and a science demonstration about atmospheric pressure. As would be expected in a demonstration, these two episodes both emphasized the teacher's voice over that of the students. Each began with a monologue introduction; however, the pedagogy demonstration continued in this manner for a substantially longer time.

In the pedagogy demonstration, Hubbard explained to her students how to do an interview with a student to gain insight into the student's understanding of a science concept. She later described the explanation:

> It was almost as if the students were watching a performance where I played all the characters. For example, when explaining how to introduce the interview, I said, "I would say… 'I have some questions written out so that …I ask you exactly the way I planned…is that all right?' 'Yes that's all right.' That way they understand what's going on. Okay?"

Later in the class, Hubbard asked Barbara to pretend to be a student so that she could model an interview. Hubbard held up several drawings of complete or incomplete circuits one at a time and asked Barbara to explain if and why the light bulb would light up. Although Barbara actually did get to speak at this point, it was, as Hubbard stated, "My ideas that are heard."

Paula (Hubbard): Do you think that the light bulb would light up? (holds up card for class to see)
Barbara: No.
Paula: Do you know…why do you say that?
Barbara: Because there isn't a little circle from this end of the battery to this end of the battery. (points to drawing)
Paula: And what do you mean by circle? What has to be a circle?
Barbara: There, there has to be another wire from here down to here, to make a circle. It's got to be a complete circuit.

Paula: That's fine. All right, I'd like to move on to another one really quickly.

This segment appears to be QAE at first glance but upon closer observation, one sees that during this time Hubbard was actually just using Barbara as a prop. Barbara's participation in the conversation does little more than demonstrate Hubbard's point of view and the ideas she wanted to convey that day.

The science demonstration included no student voices. During the introduction Hubbard lit a candle in a pan of water and covered it with a glass. As the demonstration progressed, she did all of the talking:

> Paula: Come up here and gather around this green pie pan thing. You may have seen this before. One of the things the article talked about was doing demonstrations for the class before and after, um, and make sure you can see here, up close you can stand here or whatever, um, doing a demo, before you start a unit and then asking them to write how they think it happened or asking them to explain in their own terms what's going on and then doing the same demo again at the end of the unit and having them explain it. That is not to say that during the unit you would tell them "ok, now everybody, this is the right answer about how it works" but you might talk about that general subject matter and then see if they can make the, the jump. They might ask you about it, in which case obviously you might want to answer but not necessarily would you want to tell them exactly what's happening.
>
> I've got a pie pan and there's water in it. The reason it's green is because it's a lot easier to see. I'm going to light a candle in the middle and let's think about what you think is going to happen when I cover up the candle. Then I'm going to do that and then I'd like you to think about...watch very closely to what's happening...and I'm not actually going to have you go back and write about it, but be thinking why on earth this would happen. So what's going to happen? What is happening, and why did that happen? Ok?
> (pause as students watch the demo and then go back to seats)

While science demonstrations are often QAE, Hubbard does not even seek the students' ideas during the demonstration. As in the pedagogy demonstration, the students' ideas are not heard during the demonstration itself. While we readily identified both demonstrations as monologic,

an interesting difference between the two demonstrations became apparent through the examination of what occurs following them.

After the pedagogy demonstration, Hubbard did not provide an opportunity for the students to discuss what they witnessed nor did she even ask them to evaluate what had occurred. She moved on to the next topic without any assessment of their experience. In contrast, immediately after the science demonstration, she gave the students the chance to talk in their small groups about what happened and why. Moreover, after the small group discussion, the students shared their ideas as a class:

Becky:	This may sound really, really crazy, but is there any reason why it would be attempting to get that oxygen out of the water to continue to burn?
Andrea:	I thought the same thing.
Becky:	I know that sounds really, really strange, but
Paula:	But that's why it's...you...you...think like is it as if the candle is sucking the water up so it can...?
Andrea:	Well...
Becky:	Yes, but no. I mean I understand the pressure and I agree with all of that, but at the same time, is it somehow trying to...
Cindy:	Trying to...
Becky:	Yeah, yeah...trying to...
Paula:	Well, I don't think...(Becky talks over the rest of statement.)
Becky:	Trying to extract something...
Adam:	The oxygen
Becky:	The oxygen out of the water
Adam:	That was the first thing I thought about when you first put it on. Could it possibly be the water trying to evaporate, turning the gas into oxygen and thus keeping it burning.

At this point, the students discussed how they could test this idea and eventually Barbara mentioned that the water could not be dividing into hydrogen and oxygen because in that case "it would have to be really unstable. We couldn't have campfires near lakes and stuff!"

During an interview, Newman commented to Hubbard that it was interesting that she gave the students time to discuss the science demonstration and participate in dialogic discourse,

yet she did not ever offer that opportunity with the pedagogy demonstration. As Hubbard pondered the comment, she realized her goals for both demonstrations were pedagogical. She commented, "In the science demo, I was not trying to teach about air pressure. Rather I was trying to demonstrate how a teacher might use a demonstration to assess class knowledge just as a teacher can use an interview to assess student knowledge." During the interview, Hubbard realized that she could have allowed the students to discuss the reasons behind why she was asking questions in a particular fashion, or why she had employed certain interview tools. Hubbard explained why she did not provide a discussion opportunity after the pedagogy demonstration,

> The only reason I can give is that I felt short on time. I had ten minutes left to make sure they knew what an interview looked like before they had to write their own. I knew that I could answer questions individually during work time; I was worried that if I allowed a discussion, we might not cover some major points. As a result, they would be out in the schools interviewing with little information.

Continuing the discussion of the demonstrations, Hubbard added,

> If we examine the science demonstration even more closely, one could argue that the students are still acting as my props in spite of their dialogue. At the end of the conversation, I say, "We could talk forever about why this is happening or that's happening, but that's not my main focus today." Perhaps the entire dialogue was simply a model of what this might look like much like the interview with Barbara. I ended the dialogue. My voice again became the focus, and from there the talk would go in whatever direction I chose, and I swiftly moved from participant to teacher.

While Newman agreed with Hubbard on this point, he still felt, given the student ideas articulated at the end of the science demonstration, that other voices were expressed and that segment could be labeled dialogic.

As our analysis of these two segments evolved, it became increasingly difficult to place labels science or pedagogy on them. Was the science demonstration really science if Hubbard's goal was to help the students learn to assess class knowledge? Additionally, the line between

monologic and dialogic was becoming more ill defined; simply analyzing patterns of discourse and identifying who spoke was not enough. The functions of the utterances had become critical to our analysis and the importance of voice was becoming a point of interest.

Open-ended Discussions

The two talks that represent open-ended discussion were more easily designated as science content or pedagogy, but the line between monologic and dialogic seemed more blurred. The science segment is a science talk (Gallas, 1995) about the moon, and the pedagogy segment is a discussion about science talks as an instructional strategy.

Hubbard described the science talk as, "I allow the students to discuss whatever is concerning them about the moon and ask any questions of their classmates." The talk began with a student asking a question of the class about the differing appearances of the moon. This was followed by a rich dialogue with almost the entire class participating. During the forty-minute talk Hubbard entered the conversation eight times. To us, the number of times Hubbard spoke was insignificant compared to the concept that it is difficult to tell if she is the teacher or just another student when she entered the discussion (Due to the students talking over each other and the location of microphones, it was difficult to tell who was talking, thus the students were identified by number. Also, the students were drawing on a pad of paper to explain their beliefs).

Student 1: So the first one you wouldn't see the moon because of the shadow in front of it? Is that why?
S2: You would see that on top, you would see it.
S1: You would see it start casting the shadow from the earth?
S2: Yes.
S3: Because the sun's coming around the earth and so it's not projecting all of this, like the reason why I think that...
S4: It doesn't cast much of a shadow. Here, put most of the shadow in front here, because the edges are still getting light. This one...(indeterminable) ...night time sky.

S5:	This might be a weird question, but then wouldn't you see the moon as being, go down. I don't know what I'm thinking this, but ok, ok, never mind.
Paula:	So what's the moon look like in that top picture? If I'm sitting on earth…
S4:	A circle, not a sphere, but just a circle
S6:	Really, really, I thought it was a sphere.
S4:	The eclipse?
S6:	During, at first during the eclipse.
S4:	Right.

Although Hubbard posed a question in the above segment, it was not in the role of a teacher, but rather in the role of a participant wanting clarification about a picture being drawn. Later a student changed the focus of the discussion to address his questions.

Adam:	So is the moon being lit, um, what does it look like, let's say an ordinary month. Is the moon being lit by the reflection off the earth or is it being lit by direct light from the sun?
Barbara:	I think the light is just falling in the shadow of the earth.
Cassidy:	Now I'm confused because I thought that the moon was going around the earth and that's why, how, why we see different phases, was you know, why, depending on how much light is actually hitting the moon, depending on how much of the moon we see. But, 'cause I, what I though it was, was that. Like the moon is always going around the earth or whatever, so it's going to be both of those, you know? I thought it would be like often, then I don't understand why a lunar eclipse would be such a big deal. If there's one every month…
Adam:	The moon goes around the earth. It's not exactly like boom, boom, boom, right in a row, you know?

Because the students directed the talk and discussed ideas that were important to them, Hubbard described the science talk as involving more student voice than teacher voice. "This much is clear, it is the students' ideas that are heard throughout this exchange rather than my voice as teacher. The talk is directed by the students and moves in whatever way seems to serve them best." Thus we classified this segment as clearly dialogic. While we all agreed on the multi-voice aspect of the science talk, we had some disagreement about the pedagogy discussion.

The pedagogy open-ended discussion we analyzed was about using science talks as an instructional strategy. The students had already participated in the moon talk and had seen a video of a teacher leading a discussion. Here, they discussed their opinions about the use of science talks.

Paula:	What comes to mind? Let's share a little bit. Yeah, Adam?
Adam:	Well, uh, comparing theirs to ours, ours was student led. And it was our ideas that would be coming out. Whereas the teacher was...I think the teacher was trying to...well she wasn't facilitating discussion. She was just asking questions and looking for answers. That's the difference between ours and, and you allowed us to try and answer our own problems. What appears, what appears, our answer appears to answer that question.
Paula:	Adam, do you think that, um, one kind of talk may have more value than another, or they might have different values at different times?
Adam:	Uh, it depends on the setting. You know, with, with us, yeah, we could, we could handle a discussion amongst our peers very easily, but with first graders, I think, they might be able to do it, but I, I don't think they could continue something as long, especially as we did, because they just start going off (snaps fingers) on all kinds of tangents and lose focus on what they were doing. So, it, it depends on the setting that you're in.
Cindy:	I think sometimes, at our age, it seems important to have some teacher led just because if we were to do too many group things like this, we would be almost going in circles. We need some questions to kind of guide us in what direction we need to go.
Christy:	I agree because even though we're older and should be able to stay on track, there were times when we were sitting here talking about something, like not what we're supposed to be talking about (laughter) So at least we were able to go back to that and say, so what were the questions we were after, if we got off track.
Paula:	uhhuh. So I'm hearing that there's some guidance that's needed, um...
Cassidy:	It's different for different classes. Like sometimes you'll have a class that'll be able to work together and that'll, um, do it and maybe you won't have to give much...
Cindy:	That's good. Like today, I mean, we've thought of a lot of good ideas, but if we were to repeat the same thing tomorrow and the next day and the next day...we just kept going and going and going...it's kind of...
Carla:	uhhuh
Paula:	So maybe, when do you think is a good time to have a science talk?

In analyzing this segment Newman and Hubbard disagreed about how to categorize the talk. From Newman's point of view as an observer, this segment seemed dialogic because the students respond to each other's ideas. However, the teacher role differed dramatically from the science talk about the moon. To him, it seemed that Hubbard's voice was being emphasized, and the discussion was based on her questions, moving in the direction that she chose. Hubbard acted in the role of the teacher rather than of a participant during this discussion. Accordingly, Newman classified the discussion as less dialogic than the science talk.

Hubbard, in disagreement with Newman, did not evaluate the pedagogy discussion much differently than the science talk. According to Hubbard,

> I am unsure of what I think about this segment, and I wonder if my inability to decide is based on my desire to defend my teaching practices. I feel that although the words 'I'm hearing…' would only come from a teacher, the tone and body language of the utterance are missing. Is it my voice if I'm only repeating or trying to interpret what another person said?

Hubbard then changed her focus from voice to control.

> I definitely changed the direction of the talk with my question about the appropriate time for a science talk, but I'm not sure if that makes the talk revolve around my voice. At the same time, I see that my role is that of a teacher in that only a teacher can call on students, and only a teacher could be so rude as to continually enter the conversation to summarize. So in that light, it is my voice throughout. The question that remains is, can the talk be dialogic if it is focused on my questions and my voice?

Hubbard's reflection raised questions about voice and control that go beyond speaker patterns and functions of utterances. Student ideas and voices versus teacher questions and voice became a point of debate. Moreover, the monologic/dialogic dichotomy was becoming a continuum. While the voice and intent of the teacher had played roles in our investigation, we determined that we had to formally integrate that frame into our analysis to achieve our goals.

Class Consensus Discussions

The discussions we selected for this discourse focal point both had the purpose of determining class consensus on a specific topic after the students had talked about it in small groups. In the conversation we labeled as pedagogy, the class discussed the use of portfolios in a science classroom. In the other conversation, labeled science, the class discussed their understanding of earth-moon processes.

Although punctuated by frequent instructor comments, the pedagogy talk appeared dialogic. Most of the questions were open-ended and Hubbard's contributions were, she felt, "More as a participant leader rather than teacher. For example, in [the following segment], I began with an open-ended question, which was answered by several participants. Although I asked for clarification to understand or record information, we still hear the students' voices."

Paula: What do you think Ray is capable of, and then, where does Ray's attitude rest at this point or in different points in the year? So, those are the kinds of things we're going to focus on. Overall comments?
Andrea: We've got a few pages where we're just kinda like, if it were for a parent, it seems like it's for parent teacher conferences. The parent won't have any idea how to interpret…
Paula: Can you give an example so we can all look?
Andrea: The one…like what about…it's here. (holds up page) The first page. What exactly, well, first of all, we have practice reading this, so if a parent looks at this, they, he or she, would have no idea of what…
Paula: The prediction sheet?
Carla: That bothered me.
(several students having several different conversations)
Paula: So either that needs to get out or what do you need to do?
Andrea: You should mark it or have an explanation at the top or something.
Paula: So write comments…
Andrea: Or the student could.
Carla: That in and of itself, I mean, if you had either like an audio tape…because you need the student's explanation.
Becky: Do something to help you rather than dumping it on them.
Carla: I mean for them to actually explain it.
Paula: Other overall comments?
Cassidy: He kinda loses interest. He gets this point and gets this point, but it seems like it kinda stops, and maybe he needs to work on well, he

definitely needs to work on his attitude and cooperating with others, but he doesn't need input from other people. (laughter)

Paula: So his attitude…

Cassidy: Needs encouragement

Paula: (writes on board)

Carla: I'm not sure that we have enough information to judge his attitude. I think he has a little bit of a management issue with other students, but other than that, it's hard to tell how he feels about science or how he feels about different activities. Because a lot of them are just circle or mark your answers, or…there's not a lot of his own comments, so it's hard to tell.

Although Hubbard entered the conversation at a higher frequency than other members, her purpose was to hear the voices of the students rather than to have them share ideas through her voice. This is very different than the science consensus discussion.

The science consensus discussion about the moon was almost entirely QAE. Throughout this talk, Hubbard constantly asked questions that had only one answer and tried to get the students to figure out what she already knew and to say the answer aloud. "As a teacher, I was looking for details about the moon and then organizing the students' answers on the board in the form of a chart. I never gave them the option of designing a chart or not having one at all." The entire first half of the talk followed this pattern:

Paula: So it was kind of (pause to draw) at midnight (writing on board) we were seeing it south, south east. So maybe it was going from, wait a minute, what direction is that? That's south, that's east, Ok, so maybe it was going, in the early night, it was in the east and by midnight, it had moved kind of more right in the middle (motioning with arms throughout). And apparently, we don't have any data that says what it did after that. Ok. But now, (writing) now, do we see it early night (writing) see it?

Students: (shake heads)

Paula: No. The middle of the night, like, in here (motioning to times recorded on board), maybe like, 1:45, what direction was that? Was it Cindy that saw it at 1:45? What direction was it?

Cindy: It was southeast.

Paula: Ok, southeast, then. What about these at 3:30 that time?

Barbara: South, southeast

Paula: Ok, so like 3:30 south, southeast. Now when I saw it at 10:50 it was in the south.
Cassidy: I saw it 3:30 and 5:30, and at 3:30 it was like straight east,
Paula: Straight east? Ok...
Cassidy: And by 5:30 is was traveling towards the south. So it was like just on its way...
Paula: Ok, so at 5:30 (writing on board)

According to Hubbard,

> This segment demonstrates the importance of my voice throughout the discussion. I asked all the questions. I was looking for specific answers sometimes from specific people. Only Cassidy entered the discussion without invitation, but her comments, although recorded, were met with some question of their validity. When I first read the transcription of this talk, I couldn't believe how my voice echoed throughout the discussion. Over and over I asked simple, closed questions to get students to say the answers I wanted. I began to wonder why I didn't just lecture.

Hubbard also expressed concern about teaching monologically versus dialogically, implying that monologic teaching is not quality teaching. "When I taught this lesson and we discussed it afterwards, I felt I was being very dialogic. Throughout this course I continually tried to be more dialogic in my teaching in order to hear more of the students' voices, but this segment seemed to contradict all I was trying to do."

Later in the discussion, Hubbard announced her purpose for the recitation. At one point she said,

> I think that what we need to do is establish why do we think the sun comes up and goes down, and why do we think the moon comes up and goes down? What I'm noticing in your journals is that we're, even though we say one thing in class, we're talking about it in our journals a different way. So why, how would you explain why the sun comes up?

This launched into another QAE discussion. As this particular discussion progressed, there were several instances where Hubbard indicated her control of the discussion with comments such as, "That's exactly where we need to go" or "I'm not going to deal with that right now." After having students model three main points and "feeling they were comfortable with them,"

Hubbard gave the students a problem to solve in small groups. Interestingly, after this small group discussion, the class talk moved to a much more open-ended, student-controlled conversation about what they thought and why they believed their constructs.

Paula:	I want to...In this group, did you hear them going " oh, oh, yes, yes, yes"? I want to know what that was about because that would help us even. What made you go, "waaa!"
Jennifer:	She made me go "waaaaa" (laughter)
Jennifer:	I was still thinking, no it was going this way and then she held her hand out and went like this, and then all of a sudden I saw it. And some other knowledge that wasn't fitting in before all of a sudden fit in. You know what I mean.
Cara:	Me too, and we were also talking about how fast it was going, 'cause at first I was thinking it's going really, really fast, yeah, and we're just going slower, and then Chris said it's gonna I don't know what you (looking to Chris) said, but he said it was going to go slower. I thought yeah, that makes sense 'cause yeah.
Jenny:	(indeterminable)
Cara:	yeah.
Paula:	Did any other tables have that "aha" experience or something similar. Or just, what happened?
Kate:	We were talking about how, same thing, about that rotation of the Earth and the moon moves counter clockwise, sorta what we thought about whether it would be going faster than the Earth or if the Earth would be going faster than the moon. Because like we had a pencil and a green pen was the moon it was going real slow and the black pen was going real fast, so we were kinda watching how every time we see it, every time a certain point came around to meet the moon at its orbit, it's going to look different because its moving but not very much, only a little bit, but we were wondering about, we were seeing it, because the Earth turns once on its axis every day, and so we see it once every day, we see it, it's the same with the same with the sun. The sun is not moving in the sky. It's going anywhere, the same with the moon maybe. It's moving a little bit, but it's not, we're thinking earth-centered here, so that's the problem. We're thinking it's going really fast, but it's not.

Hubbard evaluated the two consensus discussions, "Overall, the comparison of these two talks goes against what I perceive to be true as I teach. I always feel as if I teach in a more dialogic fashion when I teach something more science based, and in a more monologic fashion when I teach something more pedagogy based. I'm realizing that perhaps the line is not so easily

drawn between the two. What looks monologic may actually demonstrate student voice and sometimes recitation may be necessary to allow a student led discussion later."

As a result of the analyses of the consensus discussions, Hubbard had to question her belief that her science teaching tended to be more dialogic than her pedagogy teaching. We also discovered the need to examine her intent when teaching to fully grasp the extent to which her teaching was monologic or dialogic. While using the analysis frames of patterns of discourse, function of utterances, and voice were not extensive enough to appropriately distinguish monologic and dialogic discussions, we have not yet been able to comprehensively analyze Hubbard's rationales for the variations in her teaching.

Discussion

Following participant speaking patterns during discourse analysis allowed us to initially frame and distinguish the differences in science and pedagogy instruction. Knowing the function of the utterances also became necessary to understand the nature of the speaker's voice. Yet, defining which utterances were teacher voice and which were student voice required knowing more than by whom and when the statements were made. The role and intent of the teacher and students as they spoke also required examination. The complexity increased as disagreements about the data and analyses occurred among the instructor and the observers.

Distinguishing between science and pedagogy is not simple in an elementary science methods course. The two content areas are so intertwined that they are difficult to differentiate; moreover, what appears to be one could be assessed as the other based on the intent of the instructor and/or the perspective of the analyzer. For example, Newman questioned whether time was the sole factor in Hubbard's decision not to provide discussion time for the interview demonstration since it followed her pattern of providing students little time to discuss pedagogy

issues and much time to discuss scientific concepts. Hubbard felt the demonstrations could both be classified as pedagogy since her intent was to teach how to assess student knowledge in both and therefore the science/pedagogy dichotomy could not be readily used as a unit of analysis for these segments. Hubbard's feelings of trepidation regarding our examination of her teaching practices, an issue for any instructor being studied, also influenced the analyses of these discourse examples. We have found little common ground among our differing interpretations; thus, the two interpretations stand in juxtaposition for others to evaluate.

The two whole class discussions, while clearly defining the science/pedagogy line, blurred the monologic/dialogic line. One major issue is that, at times, high incidences of teacher voice may be necessary in the classroom; however, this does not necessarily mean the resulting discourse is monologic. Analogously, a large proportion of student voices does not mean the discourse is dialogic. Roles and intents of the speakers, as well as the function of the utterances, play an important role in determining the type of discourse. We feel that discourse cannot be analyzed by using a monologic/dialogic dichotomy. For us, discourse is better described as being on a continuum. While certain, exceptional examples of discourse may be able to be categorized as one form or the other, most cases will contain characteristics of both dialogic and monologic discourse.

Hubbard expressed two important ideas in her statements about the class consensus discussions: (a) she perceived her teaching differently after participating in self-study and (b) she expressed her desire to teach "dialogically." Self-study of classroom discourse is important if university instruction is to improve. Instructors need to reflect and examine themselves in-depth in order to move past their initial and towards more sophisticated interpretations of their work.

Through Hubbard's stated objective to teach dialogically and from interviews, it is clear she attached great importance to being able to teach dialogically and was discouraged when she teaches more monologically. However, we are not placing value judgment on either extreme of the dialogic/monologic continuum. Characteristics of each appear in most instructional discourse and value cannot be placed on the educational practices of the teacher without addressing multiple issues beyond monologism and dialogism. Other factors include, but are not limited to, function, voice, roles, and intent.

Implications

Understanding what happens in an elementary science methods course is an important step in creating a successful teacher education program. We need to understand the characteristics of discourse that occur in lessons based on the content being taught and the context of instruction. The roles of the teacher and the function of the discourse in an elementary science methods class need to be understood to inform science methods instruction. Current learning theory, including distributed cognition, informs educators of the importance of dialogic discourse in the classroom (Brown, Collins, and Duguid, 1991; Salomon, 1996), as do national science education documents (AAAS, 1993; NRC, 1996, 2000). Moreover, educational goals, learning environments, and teacher roles have changed dramatically in recent years and have influenced educators' views of effective classroom discourse (Bransford, Brown, & Cocking, 1999). Understanding discourse in science classrooms is important if preservice teacher educators are to improve their programs and promote inquiry in science classrooms. In addition to understanding the teacher's role in science classroom discourse, our research can lead to other important research projects such as examining student awareness of the differences in discourse and the effects of discourse on student achievement. By examining the teacher intents and roles more

closely, we hope to explain the differences we have uncovered and use that information to improve teacher education programs.

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SCIENCE WORK EXPERIENCE PROGRAMS FOR TEACHERS: REFOCUSING PROFESSIONAL DEVELOPMENT USING A QUALITATIVE LENS

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Introduction and Problem Statement

Science Work Experience Programs for Teachers (SWEPTs) are established to provide inservice teachers with a laboratory research position providing a first-hand experience with inquiry-based science. These programs are intended to support the creation of a classroom environment where students are exposed to instructional methods that allow for real world, inquiry-based science that is facilitated by a supportive teacher who utilizes a conceptual framework to guide instruction. SWEPTs stem from the emphasis that science education reform places on real world, inquiry-based science instruction. Documents providing a majority of the momentum for nationwide reform in science education include Project Synthesis (Harms and Yager, 1981); Project 2061: Science For All Americans (AAAS, 1989); the National Science Teacher Association's Scope, Sequence, and Coordination (Aldridge, 1989) and the National Science Education Standards (National Research Council, 1996). While the history of science education reform through an exploration of each of these national reform documents will not be discussed herein, all four of these reform documents support the teaching of real world, inquiry-based science instruction that is facilitated by a supportive teacher who is adept in using a conceptual framework to guide instruction.

Problem Statement

Despite the fact that a substantial monetary investment has been made in various SWEPTs, little information is available on the effect of these programs on the participants' classroom environments. According to results reported by Sloane and Young (1996), evaluation

efforts of SWEPTs inadequately address changes in the classroom, with most of the focus on self-reported data. Sloane and Young rank evaluation items in order of popularity as reported by participating SWEPTs (n= 35) and notes that very few of the programs report collecting data from students or direct observation of the classroom. Clearly, there is a need for a more complete evaluation of the effect of participation in a SWEPT that would include data from direct observation of the classroom. This study will examine the effect of the Columbia University Summer Research Program for Secondary School Science Teachers (Columbia's SWEPT) on the classroom environment of a teacher participant using a qualitative research approach.

Research Question

What is the effect of teacher participation in Columbia University Summer Research Program for Secondary School Science Teachers on the classroom environment?

A number of areas of interest arise within the context of the research question. Currently, these areas of interest involve a continuum of dimensions including the social constructive context and the epistemology of the science discipline as experienced in the classroom. Proposed areas of interest at the onset of the current study are as follows:

1) The relationship between program experiences and the presence of instructional activities teachers utilize to promote interest in science;
2) The interactions between the teacher and students;
3) The extent to which science in the classroom is presented as a process; and
4) The epistemological structure utilized in the classroom with respect to the extent of emphasis on theories, generalizations, and large organizing ideas in the subject domain.

Theoretical Framework

Social Cognitive Theory (Bandura, 1986) is utilized as the theoretical framework for the current study. Social Cognitive Theory explains behavior as reflective of an individual's knowledge, beliefs, and attitudes within a social context where social interactions are recognized as a powerful influence on behavior. Relying on the construct that thinking processes govern behavior, one can predict a given behavior through the examination of related knowledge, beliefs, and attitudes; however, the social context will be the lens through which the behavior will be enacted. The behavior will occur only if the social context supports it. This theoretical framework is particularly useful for the first two areas of interest because both of these concern teacher knowledge, beliefs, attitudes, and behavior.

The last two areas of interest within the context of the classroom environment concern the curriculum and lessons developed and utilized, including innovative approaches developed based on program experiences. These aspects of the classroom environment are consistent with the goal of curricular reform in science education, which is to promote inquiry in the classroom that is reflective of, and guided by, the history, nature, and practice of science (National Research Council, 1996). Curricular reform in science education emphasizes the utilization of an approach to science education that is hands-on, discovery-based, and learner-centered with an emphasis on theories, principles, generalizations, and large organizing ideas in the subject domain (National Research Council, 1996).

Literature Review

History of Professional Development in Science Content and Lack of Formal Evaluation

The history of intensive content inservice for science and math teachers begins with the summer institutes funded by the National Science Foundation in the 1960s (Council for Basic

Education, 1985). These inservice programs were designed to bring teachers to research universities where they would have the opportunity to attend content-related lectures. Another component of these programs allowed teachers to participate in laboratory experiments designed for classroom use.

While there has been a rebirth of content-focused programs in the past decade, there is a need for formal evaluation of these programs so that the effect of money and effort expended can be measured in an effort to ascertain if these resources are being expended appropriately (Council for Basic Education, 1985). The National Science Foundation urges evaluators to examine programs in terms of observable outcomes that can be directly linked to the existence of the program; the positive contribution of the program to the nation's science and math education; and the presence of program components and experiences that could be applied to future and current program development, implementation, and evaluation (Chubin, 1995).

Two Relevant Past Evaluations of the Effect of Professional Development On Teacher Attitudes and Teacher Behaviors

Teacher Attitudes

Bethel et al. (1982) seeks to determine the effect of participation in content-specific professional development on a participant's attitude towards the teaching of the content utilized in the professional development program. With respect to the effect of professional development, Bethel et al. found that a content-oriented environmental education inservice program positively influenced attitudes towards environmental science among elementary school teachers with limited experience in science. The inservice program Bethel et al. studied was a teaching methods course where an instructor more familiar with environmental education modeled for less experienced teachers how to teach various hands-on units incorporating environmental science education while the less experienced teachers participated in the activities

as elementary students. By learning more about environmental education in the context of a teaching methods course, elementary school teachers reported an interest in teaching environmental science to their students.

Teacher Behaviors

St. John (1993) exposes the problem associated with evaluating program effects through teacher self-reported questionnaires concerning teacher behavior in the classroom. St. John examined teacher behavior in the classroom following participation in professional development. St. John's videotapes of the classroom revealed that the amount of professional development in which a teacher has participated has no overall effect on the teaching style and practices even when accompanied by a change in beliefs and attitudes. While this finding suggests the need for an increased reliance on classroom observations to determine effects of program participation on the classroom environment, St. John makes no mention of the type of professional development in which the teachers participated.

History of Evaluation of SWEPTs on Classroom Environment

Self-Reported Instructional Activities

In an attempt to determine the effect of professional development programs, an evaluation of SWEPTs is documented in the literature. Kubota (1993) summarizes evaluations of SWEPTs by Andreen (1991), Beutel et al. (1991), Farrell (1992), and Kubota (1991) claiming that teachers report adopting new pedagogical techniques that promote teamwork in the classroom. Through self-report following participation in a SWEPT, teacher participants' report an increased reliance on group work where students must rely on each other to solve problems and accomplish academic goals. This inclusion of teamwork in the classroom is reflective of the social nature of science and is an important part of a constructivist classroom which is supported

by science education reform documentation.

Instructional Activities – Data from Students

Gottfried (1993) utilizes data from students to determine the impact of program participation on instructional activities utilized in class. Relying on data from students enrolled in the participants' classes, Gottfried examined the impact of participation in the University of Missouri-St. Louis' Science Teachers as Research Scientists program and found that there were no significant changes in classroom activities following participation in the program based on student answers to the Science Classroom Activity Checklist utilized in the study. Gottfried suggests that teachers may alter their views on teaching which might result in curricular and pedagogical changes not measurable by their instrument.

Self-Reported Content Utilization

A review of the literature reveals that there have been a few attempts to document changes in content utilized in class resulting from participation in a SWEPT. SWEPTs place teachers in research experiences in their content area so that they may experience inquiry-driven science while increasing their knowledge in their content area. Kubota (1993) summarizes SWEPT evaluations by Andreen (1991) and Ehrman et al. (1991) and emphasizes the new content that teachers are exposed to through program participation and the common practice of using that new content in the classroom. Again, these studies rely on self-reported data regarding classroom practices; therefore, it may be more feasible to regard this data as indicative of a participant's intentions of including new content in the curriculum that is reflective of the participant's knowledge, beliefs, and attitudes alone. Also, these studies fail to examine the frequency to which new content is utilized in class, the depth of the new content utilized in class, and the appropriateness of the new content with respect to the conceptual framework used to

structure the course curriculum.

Methodology

Appropriateness of Qualitative Approach

The current study is a qualitative evaluation of Columbia's SWEPT. According to Patton (1987), a qualitative program evaluation allows for a broader focus so that the evaluator is not limited by the preconceived ideas required when a hypothetico-deductive approach is utilized. This broader focus allows the evaluator to determine the effect of the program on its participants without need for comparisons to a framework consisting of what the program purports to do (Patton, 1987). Instead, the evaluator develops a grounded theory based on observations provided through direct contact with the program and its participants (Patton, 1987).

The richness of data provided by a qualitative study creates the possibility for an in depth study of the impact of a program on the classroom environment due to the descriptive nature of qualitative research which allows for a more complex description of the effect of the program on the classroom environment than is possible when using quantitative methods (Bogdan & Biklen, 1998). Through an interactive personal process, a greater understanding of the mechanisms underlying the relationship between the program and the participants is possible (Rossi & Freeman, 1989). Indeed, it is the subjects who determine the proper and most useful type of analysis, and in a qualitative evaluation it is the subjects themselves that drive the evaluation process. SWEPTs are developed with the needs of teachers and students as the driving force, so it is appropriate that the data from teachers and students drive the evaluation process as well.

Evaluation Design

The evaluation design for the current pilot study was a case study of a teacher participant's lived experience. Included in the evaluation design was an observation period of

the teacher participant's classroom over three weeks, two formal interviews with the teacher participant conducted during the three weeks as the teacher participant's schedule allowed, informal interviews with the participant that were brief in nature, an analysis of written student work, and an analysis of printed assignment sheets used in class during the three week period. These various data collection techniques were used in an effort to improve validity through triangulation.

Setting and Participant

Apple High School (pseudonym) in Brooklyn, New York is an educational option high school that has in attendance over 1000 students interested in pursuing a career in mechanical and electrical trades, technology, management and finance, mathematics and science, or business. The school has lower than the New York City average in daily attendance, graduation rate, Regents diploma graduation rate, verbal and math SAT scores, and teacher attendance rate (Public Education Association, 1999). The school is situated in a neighborhood of numerous rundown and abandoned buildings with many individuals of various ages loitering on the sidewalks of the neighborhood as well as those providing direct access to the school building. Students are greeted by metal detectors and numerous security officers patrolling the hallways.

The teacher participant has been teaching at Apple High School for over twenty years. The school day is divided into seven forty-minute periods, and the participant teaches three periods of Regents Chemistry with four periods for preparation and administrative work. Students in the participant's Regents Chemistry class are all in the tenth grade, and his average attendance rate in each of his classes is approximately 25 of the 30 students enrolled.

Data Collection Methods Utilized

Interviews with Teacher Participant

Interviews were used as a means of constructing data regarding the participant's program experiences and how these experiences relate to his classroom environment. Two major interviews were conducted for the present study. The first major interview was an informal, conversational interview where the participant led the direction of the flow of conversation throughout the interview period. Patton (1987) explains that this approach to interviewing allows for the natural discourse between the interviewer and interviewee to serve as both the data and driving-force of the interview. A benefit of using this approach is that the interviewer can shape questions that are specific to each interviewee as well as the current flow of conversation (Patton, 1987; Bogdan & Biklen, 1998). A set of established questions were not used for the first interview because the researcher's interest at the beginning of the study was to determine the scope of the participant's program experiences along with the scope of issues regarding his classroom environment. As a result of the researcher's intentions for the first interview, the leading question asked the participant to describe the program and his experiences in it. This question provided the context for the next leading question, and this question asked the participant to explain what goes on in his classroom. Two discussions resulted which allowed the participant and researcher to construct data together regarding the relationship between program experiences and aspects of the classroom environment such as teacher knowledge, beliefs, attitudes, and behaviors. For the second major interview, a series of questions were utilized to ensure that the conversation traveled into specific subject areas while still allowing the participant to drive the conversation into other areas of his choosing. A list of questions utilized in the second formal interview is included in Appendix A along with the rationale for each

question.

Direct Observations

Direct observations of the science classroom also provided meaningful data about the classroom environment. Through an analysis of field notes, patterns were deduced to describe the classroom environment. Patton (1987) supports the utilization of direct observation in program evaluation as a means of gathering behavioral data regarding program participants that can be compared and contrasted with data gathered via other techniques. Direct observations of the classroom were utilized in the present study to provide evidence for the support of the participant's responses in the interviews as well as to provide new information regarding the participant's classroom environment. From direct observations one can ascertain the type of instructional method used as well as the presence or absence of real world, inquiry-based science. Due to the overwhelming amount of data constructed through the utilization of classroom observations, it was necessary to organize data entry following the protocol outlined by Corsaro (1981) where "PN = personal note, FN = field note, MN = methodological note, [and] TN = theoretical note" (p. 128).

Analysis of Student Written Work and Assignment Sheets

For the current study, no statements were made regarding individual student work based on an agreement with the participant. Instead, student written work was examined only to determine the type of assignment and the science concept upon which it was based. Both student written work and printed assignment sheets were analyzed together in the present study to determine the ordering of concepts to which the students were exposed, the scope of instructional methods utilized by the participant, and the presence or absence of real world, inquiry-based science utilized in the participant's classroom.

Incorporation of The Participant's Perspective

Several strategies were utilized to incorporate the participant's perspective into the collection and analysis of the data. First, the observation records of each class were reviewed with the participant so that the participant could provide an interpretation and clarify the researcher's written record. Next, through informal interviews, the participant was asked to provide his perspective concerning the events of an observed class as well as classes for which the participant was not present. Also, student written work and printed assignment sheets were analyzed with the participant present in order to incorporate his perspective into the data collection process. Through the participant's interpretations of written materials utilized in class, an improved understanding of his views regarding his conceptual framework, his reliance upon particular instructional strategies, and the level of real world, inquiry-based science utilized in his classroom was possible. Finally, the participant reviewed the written analysis and provided feedback in an effort to further ensure that the analysis was inclusive of his perspective.

Data Analysis

Data analysis occurred after each episode of data collection. Interview transcripts were read multiple times and analyzed for common themes, and a list of these common themes was generated. The themes generated from the data included: importance of technology; interpersonal relationships; real world, inquiry-based science; conceptual framework; types of instructional activities; and school environment. An overlying theme was his dissatisfaction with his efforts in most of the previous thematic areas. Each theme on the list was assigned a color, and various sections from the transcripts were highlighted with the color corresponding to the theme of which they were representative. Classroom observation records were also color-coded as to be identifiable as representative of a given theme. Through informal interviews with the

participant at the end of the study he shared his ideas regarding the representativeness of a given section from the transcripts for a given theme.

Researcher's Role

In the current study the researcher was a fellow doctoral student with the participant and had shared numerous classes. From the beginning of the study the participant knew that he had been teaching much longer than the researcher, and the researcher also framed the study as being a means of allowing the researcher to learn more about teaching. The participant knew that the researcher was an official evaluator of the program and required to report to the program manager all findings from the study. During classroom observations the researcher sat in the back of the room as instructed by the participant, and the participant introduced the researcher to the class each period as a fellow doctoral student from Teachers College.

Findings

An analysis of the data generated numerous reoccurring themes, and while some of these themes were anticipated through the development of the research question other themes were completely unanticipated. A description of each of these themes and examples from the data follows. Evidence of the participant's expression of the overlying theme of dissatisfaction with his efforts will be included in each of the following sections as it arises.

Importance of Technology

Through interviews and classroom observations the importance of technology to the participant was apparent. The participant explained in an interview that his participation in Columbia's SWEPT allowed him to purchase a LCD projector for use in his classes.

> The program has really exposed me to all of these avenues ... like using more technology. When we got the LCD projector through the enhancement fund. And even I have a laptop with the enhancement fund so it was good.

In one day of classroom observations the participant used the LCD projector with his class to review with them recently studied chemistry concepts for an upcoming test. Next, the participant described his own relationship with technology and how Columbia's SWEPT has been instrumental in enabling him to develop this relationship by providing him internet access and by the program manager's efforts in networking with the participants throughout the school year via e-mail while encouraging teachers to network with each other along with their colleagues from their research experience. This importance he places on technology was disseminated to other departments in the school as the participant explained that he lobbied for the school administration to purchase LCD projectors and internet connections for each academic department in the school.

Interpersonal Relationships

Teachers at His School

Interviews revealed information about the participant's relationships with other teachers at his school. As leader in his department, he described helping other teachers in the department develop their lessons and providing guidance to less experienced teachers.

> There's another teacher that teaches Regents – she's a little less experienced than me. We almost do the same thing everyday. Our labs are the same. I help her.

This type of relationship extended to teachers in other departments as well, for he explained that he modeled how LCD projectors could be used in classroom instruction and taught other teachers how to use the LCD projectors in their own classes.

Fellow Teacher Participants

Another type of relationship with others that was apparent through data from interviews was the importance that he placed on the e-mail conversations he had with other program participants and his emphasis on his personal desire to further establish these types of

relationships. He reported the difficulty he has finding the time to communicate with other participants via e-mail and stressed his intentions of furthering his communications with them.

Scientists and Program Manager

He also described how he maintains contact via e-mail with the scientists he met through Columbia's SWEPT as well as the program manager.

> It's different [from other professional development programs] because they do a lot of follow up with their teachers. Jay [the program manager] keeps up with us. Yesterday, Jay sent out a joke, and he sends us copies of articles on content, most on research.

He provided examples of how he has called upon them to provide their assistance through classroom fieldtrips to their laboratories while emphasizing his personal desire to further establish these types of relationships.

> I took my students on a fieldtrip to [Physicians and Surgeons], and Jay Dubner gave them a he kind of got them on [the internet]. Yes he took them to the computer lab and taught them.... The last time he [Dr. Silverstein] gave a presentation he would throw a handful of rice before asking a question to get our attention. I'd like for him to come out to the classroom. He's a very good speaker.

Role of Scientists in Secondary Public School Education

As previously described, the participant emphasized the relationships that he has developed with scientists he has met through participation in Columbia's SWEPT, and he stressed how his perceptions of the role of scientists in secondary public school education has changed through participation in Columbia's SWEPT. Through the use of scientists as public speakers and visits to laboratories, he stressed how students begin to develop an understanding of science and the scientists themselves in an effort to support students' perceptions of scientists as people much like themselves along with his need to invite more guest speakers to class.

> They could help the teachers motivate the students help arrange visits...give them lectures on different topics...That will give the students an idea of who are

scientists -- they are real people.

His Students

Through interviews the participant explained how his relationships with his students have changed through participation in Columbia's SWEPT. The participant revealed his own feelings of inadequacy that he experienced while working in the laboratory and stressed the amount of studying he had to do to be able to understand the research in the laboratory. The participant revealed that he empathizes with those students in his class that struggle to understand chemistry concepts.

> So when I am in the situation of the student and did not know many things it really helped me to relate that way you know to really understand the problems of some students when they do not understand certain things.

Through after school support he revealed that he encourages his students.

> I try to talk to them also. Actually we have tutoring on Tuesdays and Thursdays I tell them all the time when I talk to them personally I tell them all I expect them to do is to do your best. We know that there are varieties in the classes. All are not the same. So try to do your best. And try to encourage them as much as I can.

Also, the participant stressed how participation in the program has altered how he presents himself to his students.

> But it has changed my outlook on how I do things. The labs and even the questions I give them. Oh before I used to feel really bad if perhaps I did not the answer. Yes, now I'll say that I do not know....

Long gone are the days where he views himself as the all-knowing disseminator of information, for he revealed that he is now quite comfortable with simply telling the kids that he does not know the answer to a difficult question that they might pose and encourages his students to research the answer through not only modeling the research process but also through providing opportunities for them to do the same via library resources and internet searches.

Real World, Inquiry-Based Science

The changes that the program participant has incorporated into his classroom practices include not only how he now portrays himself as a learner to his students but also in the science content that he teaches.

> And even my teaching like asking questions or giving them more chances to go into areas where they are not very familiar. That way the program has helped me to take a risk like that. Before always my attentions used to be how can I have the best regents result.

Through classroom observations, the participant revealed an emphasis on the use of everyday materials to learn science concepts. In one class observed, the participant led the class in determining the pH level of various fruits and household products. Also, through interviews with the participant, he revealed his desire to include many more real world problems in his instruction as he views an understanding of chemistry as integral to being a smart consumer.

> By learning it it changes your outlook by learning chemistry. Like if you want to go to a pharmacy and look at labels of a medicine you can look at the composition if you have already studied the formula you will get an idea of what different compounds are used. When you are talking about antacids for example anybody is going to buy an antacid will get an idea and look at the composition...can be brand name or a generic name they all have the same composition.

The participant explained that he now uses more activities in class that allow students to explore scientific concepts, but that he still wishes that he could use more real world, inquiry-based activities and stressed that he thinks real world, inquiry-based instruction results in improved student understanding.

> I think now I focus on more exploratory types of activities and I let the students explain to each other. Many times they can explain better to each other than the teacher.

Conceptual Framework Utilized in Curriculum Development

Through interviews with the participant, it was evident that he used a conceptual

framework to structure the curriculum of his Regents Chemistry course. This framework has been in place for many years with no change. His conceptual framework was hierarchical and required students to rely upon their understanding of basic concepts in order to understand more complex concepts. For example, his students learned about atoms, and then they learned about chemical reactions involving those atoms. Next, his students learned about chemical equations that involve the chemical reactions studied previously. From classroom observations and an analysis of printed assignment sheets and student work, his lessons were based upon this conceptual framework as was evident from their assignment on molar mass followed by an assignment on acid-base reactions.

Types of Instructional Activities Utilized

Group Work

Through interviews he revealed the increased value he places on group work as a result of participation in Columbia's SWEPT.

> So it works differently for different students.... Some study by talking like talking to their friends, some study by taking down notes and listening to the teacher. I try to mix it up as much as I can....

The participant also revealed his dissatisfaction with the amount of group work that his students were able to do in class along with his desire to incorporate more group work into his classes.

> I'll say that I would like the lesson to be more with student activities but the problem will be like suppose I want to show them a calculation on moles which they have no idea so I don't know how a group activity can be used to introduce something absolutely.

Individual Work

Classroom observations revealed that the participant relies on individual work as an instructional strategy. Each class observed began with a focusing instructional activity that required students to think independently. This individual work was then incorporated into a

group discussion of individuals' various ideas.

Demonstrations

Through classroom observations, the participant's reliance on demonstrations as an instructional strategy was apparent. The participant disseminated content information to students by performing experiments while the students observed. For example, in one class he demonstrated the amount of gas released from a chemical reaction via water displacement.

Laboratory Assignments

Through interviews and a review of student work and printed laboratory assignment sheets, the participant's level of reliance on laboratory assignments as an instructional strategy was apparent. Interviews revealed that the participant takes his students to the laboratory to perform experiments about once per week. Student work and assignment sheets revealed laboratory work in which students follow a series of printed steps to complete an experiment using the materials made available to them, and he expressed his dissatisfaction with using these types of lab assignments.

> To some extent I must admit that it is still unchanged. Because it's not practical just letting the students do the lab. Letting these teenagers in the lab without structure. We need to have a structure... Like one should read it and the other person should do it. The third person will record it. So that way whenever they come across a problem they discuss it and find a solution. I encourage that.

Research Projects

Through interviews and a review of student work and printed instruction sheets, the participant's reliance on student research projects was apparent. He assigned research projects that required students to use library printed materials and the internet to research a given research topic.

> Well, I'm having them write an autobiography of an element. They have to research an element. The students like that. It's a way to get them writing ...

> interdisciplinary. As science teachers we don't do a lot of that. That was from a seminar I attended for Regents. They were to use the internet or the library. They have internet in the library. Most of the time from books.... They also do research on an African American scientist.

The use of experiments as research projects was not utilized by the participant because of what he described as a lack of interest and resources of the student population while stressing his desire for his students to do these types of projects in the future.

> Currently with this present batch we do not have that. One problem that we have is that we have only very few students who are really good in doing such things and they are being put into everything so some of them do not get time to do it. Last year even Jay [program manager] had told me I could try and get my students into the lab to do some projects for Westinghouse. Maybe next year.

School Environment

The school environment was a theme that could not be ignored based on interviews, classroom observations, and the researchers own experiences travelling to the school and in the common areas of the school building.

Administration Support

Interviews revealed dissatisfaction with administration and their priorities with respect to professional development and technology. Informal interviews revealed that the administration has to be convinced to spend money on what he feels is important to his own professional development as well as the quality of his classroom instruction.

Student Population

Interviews with the participant revealed his belief that his school is doing a good job considering the student population.

> Not very hard workers. A lot of them have to work to support themselves and their families. That creates a big problem. This is my personal philosophy. Usually we tell the students to do well in the classroom, but rarely we ask them how they are doing mentally. I wish we had permission for that. As school changes we have to focus on the mental health of the children. It's a real problem

> with our school because of the special situation. The *New York Times* evaluates our school and we got four stars and this year we got a five star rating. The reason is that we are evaluated by the type of students we have attending our school and how well they have done. That makes us feel better.

His descriptions of the student population revealed students with less than average performance in math and reading, a lack of parental support, and excessive absences.

> And the parents are not that much involved to push them. So if like they have to be late picking them up or dropping them off they don't do that kind of stuff.

Next, classroom observations revealed that several students are tardy daily coupled with several students absent daily. Classroom observations also revealed that students are on task with respect to all of the observed instructional strategies utilized in class with the exception of a few students in each of the classes observed.

Neighborhood Environment

Through the researcher's own personal experiences in the neighborhood surrounding the school, the school was surrounded by rundown and abandoned buildings with many individuals of various ages loitering on the sidewalks of the neighborhood as well as those providing direct access to the school building. The participant told the researcher to take a car service to and from the school for her own personal safety.

Physical School Environment

School metal detectors as well as uniformed security were visible in the freshly painted halls of the school building. The participant's classroom revealed rows of matching flattop desks and ample passing space between rows as well as a demonstration table with gas and water at the front of the room. A trip to the laboratory revealed several laboratory tables with gas and water covered with various laboratory equipment.

Scheduling

Interviews revealed that the scheduling of students dictates his classroom instruction as well as the students that make up a given class. According to the participant, scheduling allows for each class to have one double period per week, and these dictate when the laboratory is available for a given class. With respect to scheduling, the participant teaches all Regents Chemistry classes, and he reported that his individual classes are not randomly assigned so that his classes could be ranked according to student performance if he so desired.

Discussion and Implications

Discussion

Through an analysis of the findings a greater understanding of the effect of participation in Columbia's SWEPT on the classroom environment of a teacher participant is possible. In the following sections the general themes emerging from the data will be related back to the previously described areas of interest within the context of the classroom environment.

Teacher Knowledge, Beliefs, Attitudes, and Practices

An area of interest with respect to the classroom environment is teacher knowledge, beliefs, attitudes, and practices. It is evident that of major concern to the participant is his use of technology with respect to his teaching. Through an examination of his beliefs, attitudes, and practices it is evident that the importance he places on technology translates into classroom practice with participation in the program as an enabling force to allow him to do this through financial support and improved access.

Interactions Between Teacher and Students

Participation in Columbia's SWEPT has affected the way that the participant portrays himself to his students. No longer is the participant satisfied with being the all-knowing

disseminator of information, for now he freely discusses with his students his own content deficiencies while portraying himself as a lifelong learner. Next, participation in Columbia's SWEPT has improved his sense of empathy with his struggling students. Through spending more time individually with his students in tutoring while sharing with them his own struggles, he creates bonds with his students in an attempt to encourage them to keep trying.

Science as a Process

It is not apparent that participation in Columbia's SWEPT is promoting the presentation of science as a process in the participant's classroom. Cookbook labs do not allow students an opportunity to explore and develop a sense of the nature of science as a building process. Instead, his students carry out procedures to learn about science concepts. There is no questioning induced by the laboratory assignments, and students are discouraged from straying from the protocol. One can not help but wonder if this is also the type of science to which the participant was exposed during his research experience. While the research lab in which the participant worked may have been guided by scientific questioning, it takes a long time to answer questions in the laboratory, so it may be that the participant never got to see the whole research process and was instead forced to carry out a protocol of which he was not present for the development. Unfortunately, this area of interest was not discussed in interviews, but the dissertation project for which this study is a pilot includes a period of observations and interviews while the participants are in their research settings in an effort to describe their program experiences.

Epistemological Structure of Content

The participant continues to use the same conceptual framework for his teaching which has been in place for many years. From this finding, one can conclude that participation in

Columbia's program has caused him to reconsider the framework he uses and he found no problems with it. Another conclusion based on these findings is that participation in Columbia's SWEPT had no effect on the participant's understanding of science with respect to theories, principles, generalizations, and large organizing ideas in the subject domain.

Implications

Various implications for the researcher's dissertation project can be drawn from the current pilot study. These include implications concerning methodology utilized for the dissertation project with respect to the use of a researcher journal, the use and scheduling of open and structured interviewing techniques, interviewer practices, and validity of the classroom observations as representative of a typical class for a given teacher. Implications concerning the theoretical framework utilized for the dissertation project include the need for further research on the interaction of school and classroom environment and a greater emphasis on this interaction in the theoretical framework as well as the need for further research regarding instructional technology.

Methodological Implications -- Researcher Journal

The method of recording theoretical, field, personal, and methodological notes in a typewritten journal will continue to be utilized for the dissertation project because it allows the researcher to quickly incorporate thoughts, feelings, and interpretations while transcribing interviews. Also, notes during and following classroom observations will be incorporated into the research journal while the actual classroom observations will remain in handwritten form.

Methodological Implications – Interviewing

While the first major interview with the participant was an open interview, the second major interview was more structured with a list of questions to which the researcher referred.

This pilot study allowed the researcher an opportunity to experience the variety of data that could be generated from an open interview, but it also allowed the researcher to examine the idea that when studying more than one subject issues of consistency across subjects is an issue to be addressed. For the dissertation project, the researcher will rely on open interviews to develop a working relationship with each participant and experience the variety of data generated from this type of interview while interspersing more structure interviews incorporating information from the open interviews and classroom observations in an effort to maintain consistency of questioning across participants.

Methodological Implications -- Interviewer Practices

Examining data from the interviews, researcher verbosity is an issue that must be addressed for the dissertation project. While the importance of supporting the participants as they express their personal thoughts can not be denied, the researcher must realize the difference between supporting conversation and actually introducing new ideas into the conversation. For example, in the pilot study the researcher asks the participant about his satisfaction with the way in which his room is organized, and later in the interview the researcher remarks that the desks could be slid together for lab in the classroom. The next day data from classroom observations reveals that the teacher has slid the desks together and has the students completing a lab in the classroom. This folly on the part of the researcher contaminated the interview as well as the classroom observation the next day.

Methodological Implications – Validity

The last important consideration for methodology of the dissertation project is how to determine if classroom observations represent a typical class for a given teacher. Early in the pilot study the participant withdrew from the study because he felt that the study was too time-

consuming, and following a lengthy discussion with the participant concession were made so that he would continue his work with the pilot study. Because a major data gathering technique for the pilot study was classroom observations it is possible that the participant was placing a greater emphasis than usual on the development of lessons utilized in those classes observed. As a means of determining if classes observed are representative of a typical class for a given teacher, lesson plans will be analyzed in the dissertation project. Also, surprise classroom observations will occur periodically throughout the evaluation period.

Theoretical Implications -- Utility of the Existing Theoretical Framework

The existing theoretical framework relies heavily on Social Cognitive Theory, which provides an explanation of one's actions as being the result of one's knowledge, beliefs, and attitudes. Through participation in Columbia's SWEPT, participants are placed in laboratory research settings where experiences in this lab setting influence the participant's knowledge, beliefs, and attitudes regarding science and science education. From these findings there is evidence that program participation leads to changes in knowledge, beliefs, and attitudes with respect to science education. Unfortunately, all reported changes in knowledge, beliefs, and attitudes are not coupled with a change in the classroom, and this failure to incorporate change into regular classroom practice is manifested as a personal sense of inadequacy as expressed by the participant on numerous occasions. This sense of inadequacy may have resulted in classroom observations not being representative of a typical class of the participant because the participant is only sporadically incorporating change into classroom practice. While Bandura (1986) includes the social context as an important component of explaining change in behavior, this social context which includes the school environment was not fully appreciated at the onset of the pilot study.

Theoretical Implications -- School Environment

Through a review of the findings from the pilot study, the theoretical framework will continue to be utilized for the dissertation project. Clearly, an area of emphasis that needs to be further studied through a review of the literature is the interaction of the school and classroom environments. While Bandura's Social Cognitive Theory allows for the interaction of increasingly larger social contexts, this area is a deficiency in both the development of the current theoretical framework as well as the researcher's current review of the literature. Also, Social Cognitive Theory was not initially designed to explain behavior in the school setting, so a review of the literature on teacher change may provide a better understanding of factors influencing teacher change with respect to the school environment.

Theoretical Implications -- Instructional Technology

Another area for further review of the literature concerns technological issues. Clearly, the researcher was not expecting the pilot study's emphasis on the use of technology in education. A review of the literature is needed regarding factors that enable teachers to use technology in the classroom, skill acquisition among teachers, the scope of uses of technology in the classroom, and other areas related to instructional technology.

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Appendix

First Major Interview:

1) Could you tell me about the program and your experience in it?

   (Focus question to set context for next question)

2) Could you tell me about what goes on in your class?

Second Major Interview:

1) Could you tell me about some of the things you do to get your students interested in science?

   Responses will be reflective of participant's knowledge, beliefs, attitudes, and behavior with respect to the presence of instructional activities used to promote interest in science and the extent to which science is presented as a process.

2) What is the role of scientists in secondary education?

   Responses will be reflective of participant's knowledge, beliefs, attitudes, and behavior with respect to the presence of instructional activities used to promote interest in science.

3) How did you feel being in the research lab? How do you think your students feel in your class? *Responses will be reflective of participant's knowledge, beliefs, attitudes, and behavior and interactions between teacher and students.*

4) What are the differences and similarities between your being in the research lab and your students being in your classroom?

   Responses will be reflective of interactions between teacher and students.

5) What types of instructional methods do you rely upon most? Why?

   Responses will be reflective of participant's knowledge, beliefs, attitudes, and behavior with respect to instructional strategies used to promote interest in science and the extent to which science is presented as a process.

6) Tell me about your lessons you are using in your classes. Which lesson did you do first? Why? (Interest area #6 and 7)

   Responses will be reflective of participant's knowledge, beliefs, attitudes, and behavior with respect to instructional strategies used to promote interest in science and the epistemological structure utilized in the classroom.

7) Tell me about some of the things your students would learn from doing this lesson.

   Responses will be reflective of participant's epistemological structure utilized in the classroom and extent to which science is presented as a process.

8) What do you feel is most important to teach? Why? Identify some of the ideas that you think are most important to teach in your classroom.

   Responses will be reflective of the participant's epistemological structure utilized in class and extent to which science is presented as a process.

AN EXTENSION ANALYSIS ON THE SELF-EFFICACY BELIEFS ABOUT EQUITABLE SCIENCE TEACHING AND LEARNING INSTRUMENT FOR PROSPECTIVE ELEMENTARY TEACHERS

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While the 1997 TIMSS data for grade four suggests that we are moving toward being "first in the world in mathematics and science achievement by the year 2000," these data do not indicate whether all groups of elementary students performed equally well. By contrast, the most recent National Assessment of Educational Progress (NAEP, 1996) results for 9-year-olds (fourth grade) show differences in science proficiency by race, ethnicity and gender. NAEP found that for the 9 year-old group, males out performed females, and White, non -Hispanic children scored higher than Black and non-Hispanic children with Hispanic children scoring the lowest. The NAEP results also show that 13 year-old males did better then females, that White non-Hispanic children scored higher than Hispanic children and that Black children scored the lowest.

Studies have shown gender inequity with higher academic achievement for boys than girls, classroom interactions between teacher and students that favor boys, sexual stereotyping, and gender bias in curricular materials. (American Association of University Women, 1992; Kahle & Meese, 1994; Kelly, 1985; Tobin, K., & Garnett, P. 1987) Several studies have documented that teachers interact with male students more then females (American Association of University Women, 1992, Brophy & Good, 1970; Datta, Schaefer, & Davis, 1968; Dweck & Bush, 1976; Martin, 1972; Sadker & Sadker, 1985), especially White males (Irvine, 1990; Sadker & Sadker, 1981). Jackson and Cosca (1974) and Sadker and Sadker (1981) found that

teachers interact with, call on with greater frequency, praise more highly, and intellectually challenge students who are middle class, male, and White.

Additionally, teachers have been found to lack knowledge about the history, ethnicity and culture of their children (Pearson, 1985). Allen and Seumptewa (1988) found that many of the non-Native American teachers who teach Native American students are in a quandary with the differences in the way that the children learn. These teachers often leave the reservation because they do not feel that they connect with the students. Stegemiller (1989) concluded from an analysis of 31 studies that teacher expectations for students are based on four factors: social class, attractiveness, ethnicity and perhaps gender. Thus, a white boy who comes from a middle or high socioeconomic class and is academically average to above average, has multiple advantages with the teacher over a minority girl or a student who comes from a low socioeconomic home or is academically challenged.

The inequality in interaction between teachers and students who are from low socioeconomic homes, ethnically and culturally diverse, and girls is compounded by the curriculum of science, which has been neglected in the elementary classroom (Tilgner, 1990; Westerback, 1982). This neglect is evident in the limited time teachers spend on teaching science, teachers lack of confidence in their ability to understand science content and to be able to teach that content effectively and their negative attitude toward the science curriculum.

The teachers' beliefs and interactions are critical elements in the success of all students. Elementary teachers have been known to have negative attitudes toward science (Shrigley, 1974), do not care for science (Tilgner, 1990), and do not have confidence in their ability to teach science (DeTure, Gregory, & Ramsey, 1990; as cited in Park, 1996). This in turn causes elementary teachers to avoid teaching science to children (Czerniak & Chiarelott, 1990;

Westerback, 1982, 1984) or spend less time teaching science as compared to other subjects (Good & Tom, 1985; Weiss, 1987; Westerback, 1984). Czerniak & Chiarelott, (1990) found that the negative attitudes of teachers can be correlated to students negative attitudes about science. An attitude according to Enochs and Riggs (1990) "is a general positive or negative feeling toward something" (p. 625). A belief as defined by Koballa and Crawley (1985) is "information that a person accepts to be true" (p.223). Both, however, influence behavior. Thus, teachers' attitudes, beliefs and interaction are critical elements in the success of scientific literacy for all students. It is, however, the goal of this instrument to examine the beliefs of prospective teachers as opposed to the attitudes.

Bandura's self-efficacy theory was based on a relationship that he proposed existed between personal self-efficacy and the actions and behaviors of these patients. Bandura postulated that "self-efficacy beliefs influence the course of action people choose to pursue, how much effort they put forth in given endeavors, how long they would persevere in the face of obstacles and failures, their resilience to adversity, whether their thought patterns are self-hindering or self-aiding, how much stress and depression they experience in coping with taxing environmental demands, and the level of accomplishments they realize" (p. 3).

Bandura (1995) contrasts people with different senses of efficacy as follows:

> People who have a low sense of efficacy in given domains shy away from difficult tasks, which they view as personal threats. They have low aspirations and weak commitment to the goals they choose to pursue. When faced with difficult tasks, they dwell on their personal deficiencies, the obstacles they will encounter, and all kinds of adverse outcomes rather than concentrate on how to perform successfully. They slacken their efforts and give up quickly in the face of difficulties. They are slow to recover their sense of efficacy following failure or setbacks. Because they view insufficient performance as deficient aptitude, it does not require much failure for them to lose faith in their capabilities. They fall easy victim to stress and depression (p. 11).

On the other hand:

> People who have strong beliefs in their capabilities approach difficult tasks as challenges to be mastered rather than as threats to be avoided. Such an affirmative orientation fosters interest and engrossing involvement in activities. They set themselves challenging goals and maintain strong commitment to them. They invest a high level of effort in what they do and heighten their effort in the face of failures and setbacks. They remain task-focused and think strategically in the face of difficulties. They attribute failure to insufficient effort, which supports a success orientation. They approach potential stressors or threats with the confidence that they can exercise some control over them. Such an efficacious outlook enhances performance accomplishments, reduces stress, and lowers vulnerability to depression (Bandura, 1995, p. 39).

Bandura's philosophy of the self-efficacy construct included his theory that self-efficacy beliefs affect how people think, act, feel and motivate themselves concerning all aspects of their lives. He interpreted, however, efficacy beliefs as having varying levels of importance. The most fundamental beliefs are those around which people structure their lives (Bandura, 1997, p. 43). Such beliefs have predictive value because these types of beliefs guide which activities are undertaken and how well they are performed. Bandura found this predictive value to be of the utmost importance because it gave way to the fact that if the self-efficacy beliefs of people could be influenced, people could achieve at levels they once thought they were incapable.

The self-efficacy construct, as described by Bandura, consists of two cognitive dimensions: personal self-efficacy and outcome expectancy. Bandura (1977, 1981, 1986, 1995, & 1997) defined personal self-efficacy as "judgments about how well one can organize and execute courses of action required to deal with prospective situations that contain many ambiguous, unpredictable, and often stressful elements" (p. 201). Bandura (1977) portrays outcome expectancy as "a person's estimate that a given behavior will lead to certain outcomes. An efficacy expectation is the conviction that one can successfully execute the behavior required to produce the outcomes. Outcome and efficacy expectations are differentiated, because

individuals can believe that a particular course of action will produce certain outcomes, but if they entertain serious doubts about whether they can perform the necessary activities such information does not influence their behavior" (p. 193). Bandura (1997) also noted that people who believe that their behavior can influence the outcome of a situation act more assertively then those who believe that outcomes cannot be influenced by their behavior.

The construct of self-efficacy beliefs is grounded in social learning theory and is the product of a complex process of self-persuasion that relies on cognitive processing of diverse sources of efficacy information. These include performance accomplishments, vicarious experience, verbal persuasion and emotional and physiological arousal.

Currently, 25 of the 50 largest school districts in the United States have children of color as the majority student population (Banks, 1991). In states such as New Mexico, Texas and California children of color comprise 70 percent of the total student population (Quality Education for Minorities Project, 1990). Children of color make up 30 percent of the students in the country overall and the growth rate of the minority population segment is expected to increase to 40 percent by the year 2020 (Pallas, Natriell, & McDill, 1989). By contrast, when the demographics of the prospective elementary teacher population is examined, it is found to be predominately white, middle class and female (Banks, 1991). The elementary teacher population continues to be Caucasian, monolingual, and female with backgrounds different from those they will teach, while the face of the school population in the United States is becoming more diverse (American Association of Colleges of Teacher Education, 1987; Banks, 1991; Ducharmen and Agne, 1989; Haberman, 1987).

Science for All Americans (1989) recognizes these inequalities and proposes that scientific literacy needs to be a goal of school science education for <u>all</u> young people, "those who

in the past who have largely been bypassed in science and mathematics education: ethnic and language minorities and girls" (p. xviii). Questions concerning how scientific literacy can be achieved given inequality in interaction due to race, class and gender differences and teacher beliefs concerning the science curriculum are vital.

To ensure scientific literacy for all, it is important for elementary teachers to understand student diversity and be able to teach science for a diverse student population. Part of the solution may be in understanding the behaviors of prospective elementary teachers. Teacher beliefs appear to be good predictors of behavior (Ashton & Webb, 1986a, 1986b; Bandura, 1986; Riggs, 1988; Enochs & Riggs, 1990). Teacher self-efficacy beliefs, in particular, have been found to be valid predictors of practicing and prospective elementary teachers' behavior regarding science teaching and learning (Ashton & Webb, 1986a, 1986b; Bandura, 1986; Riggs, 1988; Riggs & Enochs, 1990).

Purpose of the Study

The purpose of this study was to develop, validate and establish the reliability of an instrument to assess the self-efficacy beliefs of prospective elementary teachers with regards to science teaching and learning for diverse learners. This is an important area of self-efficacy belief assessment for which an instrument does not exist. The study built upon the work of Ashton and Webb (1986a, 1986b) and Bandura (1977, 1986), and the instrument was modeled after the Science Teaching Efficacy Belief Instrument (STEBI) (Riggs, 1988) and the Science Teaching Efficacy Belief Instrument for Prospective Teachers (STEBI-B) (Enochs & Riggs, 1990). It was proposed to be titled Self-Efficacy Beliefs about Equitable Science Teaching (SEBEST).

According to Bandura, (1986, 1997), the construct of self-efficacy beliefs consists of the two dimensions: personal self-efficacy and outcome expectancy. Personal self-efficacy "is a judgment of one's ability to organize and execute given types of performances, whereas an outcome expectation is a judgment of the likely consequence such performances will produce" (Bandura, 1997 p.21). An aim in developing the SEBEST was for each of the dimensions of self-efficacy beliefs of prospective elementary teachers toward teaching learning science for diverse learners, i.e., personal self-efficacy, outcome expectancy (Bandura, 1986), to be represented as a subscale.

The SEBEST instrument was designed to assess preservice teachers self-efficacy and outcome expectancy beliefs with regard to teaching and learning science in an equitable manner when working with diverse learners. This is the context in which the term "equitable" was used in developing the SEBEST and it is used in this paper.

Development of the SEBEST

A seven-step plan was used to develop the SEBEST and build validity and high reliability into the instrument.

Step 1: Defining the Constructs and Content to be Measured

Diverse learners as recognized by *Science for All Americans* (1989) are "those who in the past have largely been bypassed in science and mathematics education: ethnic and language minorities and girls" (p. xviii). That definition was extended to include children from low socioeconomic backgrounds based on the research by Gomez and Tabachnick (1992). They found that the views of prospective teachers toward minority children and children from low-income families limit the children's opportunities to learn and prosper from schooling. Similarly, the work of Grant and Tate (1995) acknowledges "educational research becomes

problematic when it does not include race, class, and gender, and/or when these constructs are not rigorously interrogated" (p. 147). For example, *The IEA study of Science II: Science Achievement in Twenty-three Countries*, found that family economic factors, the educational level of the parents, the size of the family, and the amount of reading material in the home were related to achievement in science (Postlethwaite & Wiley 1992). Baker (1998) proposes that "parental attitudes and economic condition of the family could be the major determinant of whether a girl will receive an education" (p. 879).

Figure 1 presents the Content Matrix that was developed for use in this study to define the content for the SEBEST. It is composed of the self-efficacy construct (i.e., personal self-efficacy and outcome expectancy dimensions), the definition of diverse learners developed for the study (i.e., ethnicity, language minorities, gender, and socioeconomic dimensions), and the phrasing dimensions for Likert items to be included in the SEBEST (i.e., positive and negative).

Step 2: Draft Item Preparation

Information on practices that are effective for teaching science to diverse student populations explicated in science education and multicultural education research, (for example, AAUW, 1992; Kahle & Meese, 1995; Kelly, 1985; Tobin, 1996, Atwater, 1994; Brickhouse, 1994; Gomez, 1996; Hodson, 1993; Rakow, 1985; Spurlin, 1995) informed the preparation of draft items for the SEBEST. One hundred ninety-five Likert type items, modeled after those composing the STEBI (Riggs, 1988) and STEBI-B (Enochs & Riggs, 1990) were drafted with at least six representatives for each cell in the Content Matrix presented in Figure 1.

Edward's (1957, pp. 13-14) fourteen guidelines for building item clarity also were used as a guide as draft items were written to reduce item error due to ambiguity. These guidelines include

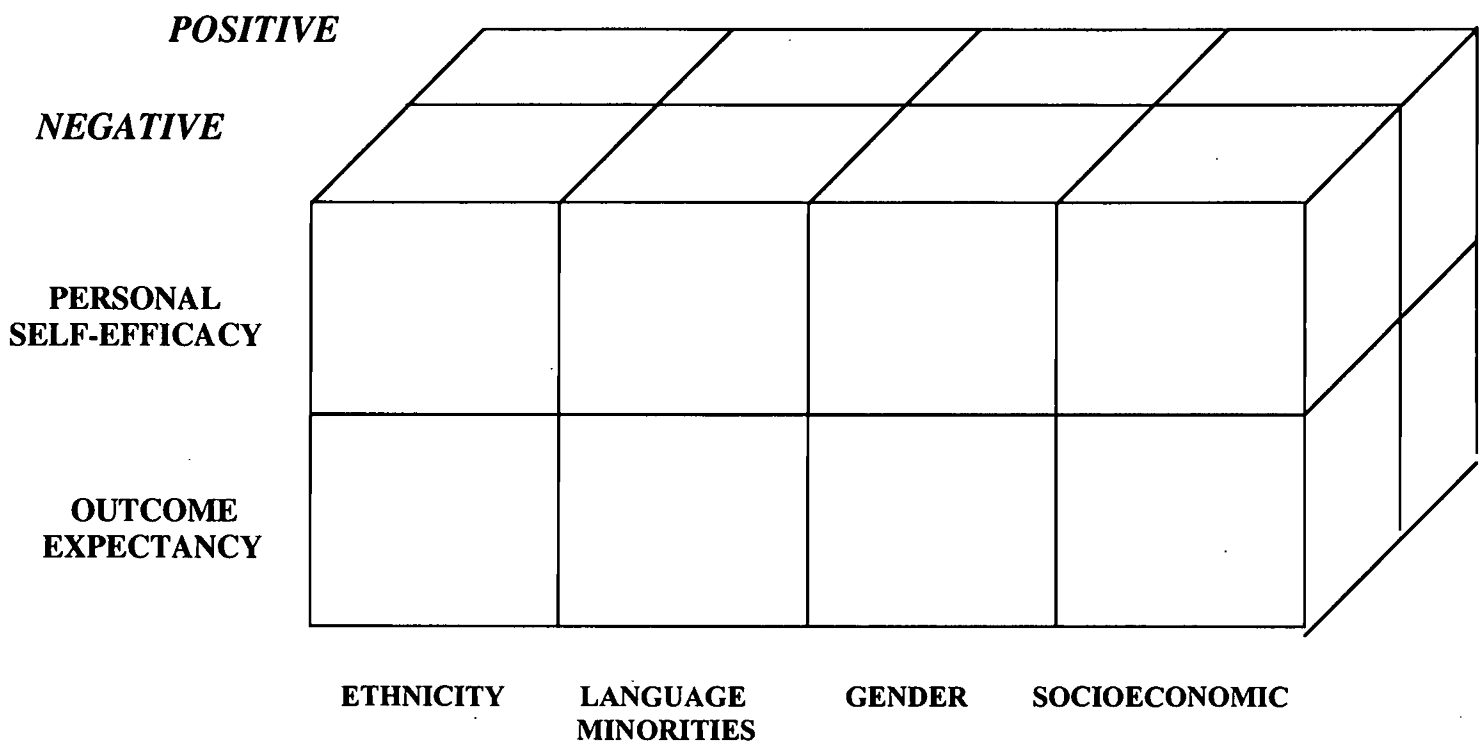

Figure 1. Content Matrix for the Self-Efficacy Beliefs about Equitable Science Teaching (SEBEST).

points, such as: (a) use items that refer to the present verses the past, (b) use simple, clear and direct language, (c) items should not use "all," "always," "none" or "never," (d) use care in using "only," "just" and "merely," and (e) avoid double negatives.

Step 3: Draft Item Review

A letter that explained the review task and the 195 draft items were submitted to 10 graduate students in Science Education at The Pennsylvania State University. Edward's criteria and the definitions of self-efficacy beliefs, personal self-efficacy, outcome expectancy, ethnicity, language minorities and gender also were included. The graduate students independently reviewed each of the draft items for clarity and comprehension by prospective elementary teachers. Comments for improvement was recorded directly on the draft items.

The feedback was used in revising the draft items. The revised items were resubmitted to the graduate students and subsequently revised until all ten graduate students judged that clarity and comprehension was achieved for at least five items in each cell of the matrix. Eighty items were identified within two rounds of review.

Step 4: Revised Item Content Validity

A panel composed of eight faculty members from inside and outside of The Pennsylvania State University representing science education, multicultural education, and self-efficacy research, was constituted for the purpose of judging the content validity of the eighty revised items. The panel members were given a letter of explanation, the revised items, the definitions of terms used within the instrument and Edwards's criteria. They worked independently to judge the content of the items and their feedback was used to revise the items. The items were to be resubmitted to the faculty members until at least four items in each cell of the Content Matrix (Figure 1) were judged content valid by five of the judges. However, this proved unnecessary

given that a sufficient number of the items, 48 with at least 6 items representing each cell in the Content Matrix, were judged content valid after one review. Those 48 content valid items constituted the "first draft" of the instrument.

Step 5: First Draft Instrument Try Out

The "first draft" instrument was administered to the 124 prospective elementary teachers in the five sections of SCIED 458--Teaching Elementary School Science and the 102 prospective elementary teachers in the nine sections of Elementary Student Teaching at The Pennsylvania State University during the second week of November 1998. These accessible groups represented the intended population for the final instrument. The resulting data were used in formulating the SEBEST as described in Step 6, below.

Step 6: SEBEST Formulation

The task in Step 6 of the development was three-fold: to identify a subset of the 48 items that: a) was construct valid, b) had high internal consistency reliability, and c) was representative of the Content Matrix presented in Figure 1. Factor analysis was used to help identify a construct valid subset of items. Coefficient Alpha, a measure of internal consistency, was used to examine the reliability of groups of items, item to total score correlation was used to determine the contribution of an item to total instrument score, and Chi Square was used to check item representation across the Content Matrix. Because the three qualities can be antithetical to one another – for example, the most construct valid and reliable set of items might not be representative of the Content Matrix -- these statistical techniques were applied multiple times and in combination to help select items for the SEBEST that gave the instrument the strongest profile across all three qualities.

The data used for these analyses were collected in step 5 by administering the 48-item "first draft" instrument to the 226 prospective elementary teachers in The Pennsylvania State University Elementary-Kindergarten Teacher Education (EK ED) program. Again, these included the students in the five sections of SCIED 458--Teaching Science in the Elementary School (n = 124) and in the nine sections of Elementary Student Teaching (n = 102) during the Fall semester of 1998. Usable data were secured from 217 of these prospective elementary teachers -- 120 of the students in SCIED 458 and 97 of the students in Elementary Student Teaching. The mean score on the 48 items among the 217 prospective elementary teachers was 151.45 with a standard deviation of 10.97 (scores on the 48 five-point Likert item instrument could range between 48 and 240).

Initial Factor Analysis Results

These data were subjected to Principal Component Factor Analysis using Varimax Rotation. The analysis generated 14 factors with an Eigenvalue of 1.00 or greater, that accounted for 64% of the variance in the instrument results. Because the desire was to select the smallest subset of the items that were construct valid, had high reliability and were representative of the Content Matrix, a Scree Plot was used to visually examine the number of factors and determine the number of significant factors. The Scree plot for the analysis is presented in Figure 2.

According to William and Goldstein (1984) the number of significant factors, or number of component factors to be retained, is indicated by a significant change in the slope of the plot set by a algorithm in the SPSS program -- the point at which the Scree plot curve breaks and forms a relatively straight line by a series of smaller, non-significant, Eigenvalues. In Figure 2, the point at which the contour of the curve changes significantly is marked with an arrow -- at an

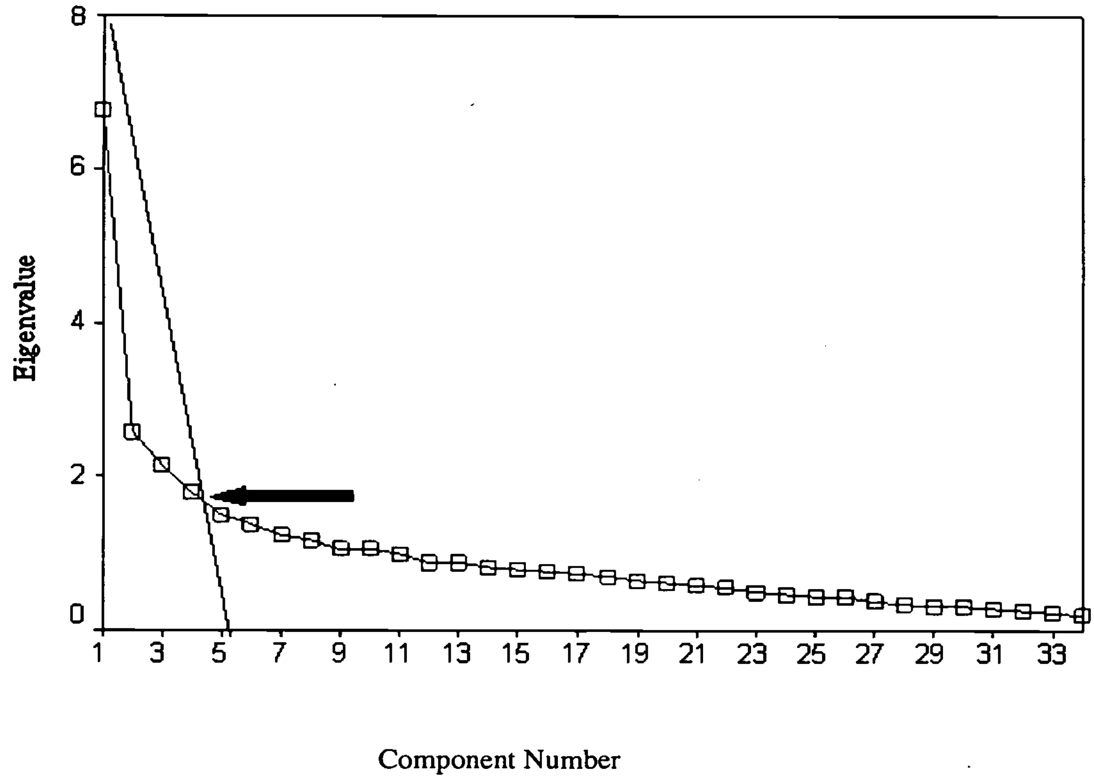

Figure 2. Scree Plot.

Eigenvalue of 1.7 and four components. Four factors were identified as significant using this method. Twenty-eight items loaded on these four factors. From a factor analysis perspective alone, the instrument might include 28 items.

The contribution each of the 48 items made to total instrument scores and reliability also was examined to determine the possible composition of the instrument from a reliability perspective. Thirty-four items were judged to be appropriate for inclusion in the instrument based on this perspective. That is, the 34 items that had the highest item to total instrument score correlations generated the highest Coefficient Alpha reliability for the total instrument and two subscales, i.e., personal self-efficacy, outcome expectancy.

Second Factor Analysis Results

The 34 items were subjected to Principal Component Factor Analysis using Varimax Rotation. These items loaded across four factors, which accounted for 39.2% of the variance in the data. Table 1 shows the item loading across the 14 factors, the variance accounted for by each factor and cumulatively across them, and the Content Matrix category for each item. As is noted, Factor 1 accounted for 11.6% of the variance in the instrument results, Factor 2 for 9.5%, Factor 3 for 9.3%, and Factor 4 for 8.9%. These percentages showed balanced variance across the four factors.

Additionally, the item factor loadings for the four factors were pure, with each factor being associated with either the Personal Self-Efficacy (PSE) or Outcome Expectancy (OE) dimension of Self-Efficacy. Eleven items loaded on Factor 1, all associated with Personal Self-Efficacy (PSE), particularly socioeconomic status, gender and ethnicity. Factor 1, therefore, was identified with PSE. Ten items, all of which were associated with Outcome Expectancy (OE) with language minorities, socioeconomic status, gender and ethnicity represented loaded

Table 1
Factor Analysis Results for 34 Items

Items No. Old	New	Factor 1	Factor 2	Factor 3	Factor 4	Matrix Cell*
1	1			0.71		PSE:LM
2	2	0.49				PSE:SES
3	3				0.47	OE:G
4	4		0.54			OE:E
5	5	0.63				PSE:E
6	6			0.65		PSE:LM
7	7	0.56				PSE:G
8	8		0.64			OE:E
9	9			0.76		PSE:LM
10	10	0.49				PSE:G
12	11				0.65	OE:E
14	12		0.50			OE:LM
15	13		0.63			OE:G
16	14		0.68			OE:E
17	15			0.65		PSE:LM
18	16	0.30				PSE:G
19	17				0.61	OE:SES
21	18				0.64	OE:G
22	19	0.69				PSE:E
24	20	0.38				PSE:E
25	21		0.42			OE:G
26	22	0.67				PSE:SES
28	23		0.45			OE:SES
29	24	0.79				PSE:E
30	25				0.49	OE:G
31	26			0.60		PSE:LM
34	27	0.67				PSE:E
40	28		0.42		0.29	OE:SES
41	29		0.53			OE:LM
42	30				0.64	OE:E
43	31		0.36		0.55	OE:SES
44	32	0.38				PSE:G
45	33		0.72			PSE:LM
48	34				0.39	OE:LM
% of Variance		11.6	9.5	9.3	8.9	
% Cumulative Variance		11.6	21.1	30.3	39.2	

* PSE = Personal Self Efficacy; OE = Outcome Expectancy
E = Ethnicity; G = Gender; LM = Language Minority; SES = Socioeconomic Status;

Factor 2. Six items identified with PSE loaded on Factor 3, all associated with language minorities. Eight items associated with OE, but from across the Content Matrix, loaded on Factor 4. The reliability of the PSE items that loaded on Factor 1 was .82 and on Factor 3 was .80. The reliability for the OE items that loaded on Factor 2 was .72 and on Factor 4 was .75.

Chi Square Results

Table 2 shows the distribution for the 34 items across the Content Matrix presented in Figure 1. A Chi-Square test was used to determine whether the 34 items were balanced across Personal Self-Efficacy/Outcome Expectancy and Ethnicity/Language Minority/Gender/ Socioeconomic Status for the PSE and OE dimensions of the Content Matrix. The resulting statistic, $X^2 = 2.71$, $df = 7$, was not significant at the .05 level of probability. This was interpreted as evidence that each of the two dimensions of the self-efficacy construct and each of the four diverse groups of learners were represented in the 34 item instrument to no significant difference.

The SEBEST Instrument

The task in Step 6 was to identify a subset of the tryout items that was construct valid, had high internal consistency reliability and was representative of the Content Matrix. Thirty-four items achieved this goal -- gave the instrument the strongest profile across all three qualities -- and so were used to compose the Self-Efficacy Beliefs about Equitable Science Teaching or SEBEST instrument. The 34 item SEBEST is presented in Appendix A. The even items compose the Personal Self-Efficacy or PSE Subscale, and the odd items compose the Outcome Expectancy or OE Subscale.

Table 2
Distribution of the 34 Items Across the Content Matrix

Dimensions/ Items	Ethnicity	Language Minority	Gender	Socioeconomic
Personal Self Efficacy	#7,#19,#27 #29,#33	#1.#5,#9,#13 #21,#25	#11,#15,#23 #31	#3,#17
Items 3, 9, 13, 21, 23, 27, 29, and 33 need to be reversed coded.				
Outcome Expectancy	#4,#12,#16 #22,#32	#18,#30, #34	#2,#8,#20, #26,#28	#6,#10, #14,#24
Items 4, 6, 8, 12, 14, 18, 22, 28 and 30 need to be reversed coded.				

Coefficient Alpha Reliability Results

Coefficient Alpha was used to assess the reliability of the 34 item SEBEST and its two subscales using data secured from the 217 prospective elementary teachers. The reliability of the entire instrument was found to be .87. The reliability was .83 for the 17 PSE items or subscale and .78 for the 17 OE items or subscale. A reliability of .87 indicates that 76% of a respondent's score is true score variance and 24% due to error. Similarly, a reliability of .83 indicates 69% true score while 31% is error, and a reliability of .78 indicates that 61% is true score and 39% is due to error.

According to standards presented by Helton, Workman and Matuszchk (1982), a reliability coefficient of .90 or higher is desired for classroom classification decisions, although this benchmark is rarely met. Remmers, Gage and Rummel (1965) support a reliability coefficient of .80 or higher for school use and .70 or higher for research instruments, especially

if group performance is only an issue. Reliability coefficients above .90 are considered necessary to make individual decisions with instrument results; above .80 are considered for research; and above .70 for initial group decisions that will be tested through additional means. (Nunnally, 1970) The reliability coefficient of .87 on the 34 item SEBEST, and .83 and .78 on its subscales were interpreted as being well within the acceptable reliability range for a research instrument.

Step 7: Further Study of Reliability

The internal consistency and test-retest reliability of the 34 item SEBEST were examined with data from two other samples of prospective elementary teachers (samples of convenience) during the Spring of 1999. One consisted of 23 prospective teachers enrolled in the Urban Early and Middle Childhood Education Program (URBED) at The Pennsylvania State University Delaware Campus, a teacher education program with an urban education focus. These prospective elementary teachers were at the mid-point of their student teaching experience in an urban elementary school. They had completed all of the required coursework for a BS degree and elementary teacher certification in Pennsylvania, including URBED 403--Using Science and Mathematics Knowledge and Assessment in Urban Settings along with an associated in-school (urban) clinical experience during the Fall semester of 1999. The purpose for including the urban preservice elementary teachers was to widen the diversity of the respondents to the instrument.

The other sample consisted of 102 prospective teachers enrolled in the Elementary-Kindergarten Teacher Education Program (EK ED) at The Pennsylvania State University University Park Campus. These prospective elementary teacher were at the mid-point of completing SCIED 458--Teaching Science in the Elementary School, along with mathematics

and social studies teaching and learning courses and an associated in-school clinical experience. The vast majority would be student teaching during the next semester (Fall 1999) and graduating with a BS in Elementary-Kindergarten Education and Pennsylvania elementary teacher certification. The EK ED students also completed the SEBEST twice: at mid-semester and at the end of the semester.

It should be noted that while one preservice teacher sample came from an "urban" teacher education program, both programs were conceptually similar, including the science pedagogy courses. Additionally, the purpose was not to compare the two samples on the instrument, but rather to study its reliability.

The Coefficient Alpha reliability for the SEBEST at mid-semester with the URBED prospective elementary teachers was .90, .81 for the PSE subscale, and .88 for OE subscale. At mid-semester, the reliability of the SEBEST with the EK ED prospective elementary teachers was .88 -- .83 for the PSE subscale, and .85 for OE subscale. The reliability of the SEBEST with the EK ED prospective elementary teachers at semester's end was .92 -- .87 for the PSE subscale, and .86 for OE subscale.

A Pearson-Product Moment correlation coefficient was calculated using data from the EK ED prospective teachers who completed both SEBEST administrations (n = 90) to estimate test-retest reliability, which was estimated to be .70 -- .70 for the PSE subscale and .67 for the OE subscale. These are considered to be estimates given the respondents were engaged in a methods course between the test and retest.

<u>Further Test of Construct Validation</u>

A Rasch analysis of the data was conducted in order to further evaluate the functioning of the instrument. Specifically considered were Rasch fit statistics, the distribution of Rasch

calibrated survey items with regard to the latent trait, item reliability, and a principal component analysis of standardized residual correlations. These statistics have been used in a wide range of studies to evaluate the functioning of scales: see *Rating Scale Analysis* (Wright and Masters, 1982) for a full discussion of these issues. The analysis was conducted through use of the Rasch computer program Winsteps (Linacre and Wright, 2000).

Rasch fit statistics provide insight with regard to the functioning of an instrument. These statistics applied to survey items defining a scale help one evaluate whether or not an item is responded to in an idiosyncratic manner by respondents when all other responses to items are considered. In essence this statistic helps one learn if all items authored to define a latent trait (or variable) in fact do so. Analysis of both the personal self-efficacy and outcome expectancy scale revealed that no items appeared to generate high fit statistics. This suggests strength in the functioning of the scale.

Evaluating the manner in which items define a specific latent trait is another commonly used technique of assessing the functioning of tests and rating scales. In both scales (outcome expectancy and personal self-efficacy) there is a good distribution of items defining the latent trait. That means there are a range of items that are, for instance, easy to agree with and there are a range of items which are less easy to agree with (in relation to other items presented on the scale). Rasch item reliabilities were calculated for both the outcome expectancy subscale (.81) and the personal self-efficacy subscale (.98). These statistics help suggest good reliability.

One slight improvement, which might be explored in subsequent versions of this scale, is the use of a separate rating category scale for outcome expectancy and personal self-efficacy. The reason for this is that respondents appear to have a higher probability of utilizing the

strongly agree and agree categories for the outcome expectancy scale, where as these same respondents have a tendency to utilize more of the five-point scale for personal self-efficacy.

A principal component analysis of standardized residual correlations for items was computed for both subscales. Table 3 presented the outcome expectancy analysis, while Table 4 presents the statistics for personal self-efficacy. As part of that analysis, factor loading and person measures where evaluated. That analysis suggested that no SEBEST items define the factors other than those utilized for each subscale.

Conclusions

Based on the standardized development procedures used and the associated evidence, the SEBEST appears to be a content and construct valid instrument, with high internal reliability qualities, for use with prospective elementary teachers to assess personal self-efficacy beliefs for teaching and learning science for diverse learners. We suggest that this scale can be utilized in a number of ways. First, it can be used for the computation of mean linear measures based upon a set of items, for example, computation of a student's personal self-efficacy measure and outcome expectancy measure. This is the traditional way in which the SEBEST and others (e.g. Enochs and Riggs, 1990) have been used. However, we also suggest that the SEBEST can be used to help understand what it means to have a particular belief measure based upon a set of items such as the SEBEST. Figures 3 and 4 present plots that quickly convey the relationship between a preservice teacher's mean (average) raw response to SEBEST subscale items and their predicted responses to individual items in the subscale. The data for these two "most probable response plots" were collected from prospective elementary teachers during the Spring of 1999 and subjected to Rasch Analysis. Each horizontal line in the two plots shows the

Table 3
Rasch principal component analysis of standardized residual correlations for personal self-efficacy items

Loading	SEBEST	Item
.74	29	I will be able to successful teach science to children of color.
.74	17	I will have the ability to help children from low socioeconomic backgrounds be successful in science
.62	23	I cannot held girls learn science at the same level as boys
.54	11	I can help girls learn science at the same level as boys
.53	31	I will be able to help girls learn science
.47	33	I will not be able to teach science successfully to White children
.40	15	I will be effective in teaching science in a meaningful way to girls
.33	27	I will not be able to successfully teach science to Asian children
.32	19	I will be able to successful teach science to Native American children.
.15	7	I will be able to meet the learning needs of children of color when I teach science.
.10	3	I do not have the ability to teach science to children from economically disadvantaged backgrounds.
-.61	21	I will not be able to teach science to children who speak English as a second language as effectively as I will be children who speak English as their first language
-.58	13	I do not know how to teach science concepts to children who speak English as a second language.
-.58	5	I can do a great deal as a teacher to increase the science achievement of children who do not speak English as their first language.
-.44	1	I will be able to effectively teach science to children whose first language is not English.
-.41	25	I will be able to effectively monitor the science understanding of children who are English Language Learners.
-.32	9	I do not know teaching strategies that will help children who are English Language Learners Achieve in science.

Table 4
Rasch principal component analysis of standardized residual correlations for outcome expectancy items

Loading	SEBEST Item	
.64	4	Even when teachers use the most effective science techniques in teaching science, some Native American children cannot achieve in science.
.57	12	Even when teachers use the most effective science techniques in teaching science, some children of color cannot achieve in science.
.27	6	Good teaching cannot help children from low socioeconomic backgrounds achieve in science.
.05	22	Children of color cannot learn science as well as other children even when effective science teaching instruction is provided.
.03	18	Children who speak English as a second language are not able to achieve in science even when the instruction is effective.
.01	16	Children of color can succeed in science when proven science teaching strategies are employed.
.01	24	A good science teacher can help children from impoverished backgrounds achieve in science at the same level as children from higher socioeconomic backgrounds.
-.62	26	Girls can develop in science at the same level as boys if they receive science instruction that is effective.
-.55	28	Girls do not have the ability to learn science as well as boys, even when effective teaching techniques are used.
-.44	32	White children can learn science as well as other children when effective science teaching is employed.
-.42	2	Girls can learn science if they receive effective science instruction.
-.26	30	children who are English Language Learners do not have the ability to be successful in science even when the science instruction is effective.
-.26	10	Effective science teaching can help children from low socioeconomic backgrounds overcome hurdles to become good science learners.
-.18	8	Girls are not as capable as boys in learning science even when effective instruction is provided.
-.17	20	Girls have the ability to compete academically with boys in science when they receive quality science instruction.
-.07	34	Children who are English Language Learners can be successful in learning science if the teaching is effective.
-.05	14	Effective science teaching cannot improve the science achievement of children from impoverished backgrounds.

predicted distribution of responses for each individual subscale item as a function of students' measures based upon the subscale (noted along the lowest horizontal line of both figures).

These "most probable response plots" (Figures 3 and 4) add understanding to SEBEST responses and scores in four important ways. First, the plots can be used to predict responses on a subset of items or an individual item in a SEBEST subscale when only selected responses to other items in the subscale have been made. For example, draw a vertical line from respondent #7 upward on Figure 3. This line shows that this prospective elementary teacher should have (from a probabilistic point of view) responded to items 21, 1, and 13 with the selection of the "agree" rating. It also shows that prospective elementary teacher #7 is likely to have responded to the remaining items with the selection of "strongly agree".

If only limited data were collected from a respondent, a set of responses to selected items would still allow one to predict what might be a candidate's answers to items that were not administered. This technique outlined in Figures 3 and 4 is currently being used in medicine to bring meaning to a "raw score" beyond what the "average" response of a candidate might be. In fact, this type of plot allows one to not necessarily administer all items of the survey, for the plot can be used to predict responses. Nonetheless, we suggest that the SEBEST be used in traditional ways, through the use of a total measure based initially upon a set of items, but also that figures such as 3 and 4 be utilized to better understand the meaning of a respondent's mean measure. Particularly powerful is to display the mean measure of subgroups of respondents on SEBEST subscales and how groups of respondents (e.g. white students, African American students) differ beyond the simple use of a mean measure.

Second, the plots show how likely a response (e.g., strongly agree, agree, uncertain, disagree, strongly disagree) is for a respondent to a set of items -- in the case of Figure 3 for the

```
|------+------+------+------+------+------+------+------|  ITEM
|                            SA   :    A   :   U DSD      Q23-R I Can Help Girls Learn
|                            SA   :    A   :   U DSD      Q31  I Can Help Girls Learn Sci
|                            SA   :    A   :  U  DSD      Q11  I Can Help Girls Learn Sci
|                            SA   :    A  :   U  DSD      Q15  I Will Be Effective Teaching Meaningful Way Girls
|                                                 |
|                        SA    :    A    :    U  :DSD     Q29   I Can Teach Child Of Color
|                                                 |
|                       SA   :    A   :    U    : DSD     Q7    Can Meet Learning Needs of Children Color
|                       SA   :    A   :    U    : DSD     Q17   I Can Help Low SES Students
|                      SA    :    A   :    U   :  DSD     Q33-R I Can Teach Sci To White Children
|                     SA   :     A   :   U    : D SD     Q27-R I Can Teach Asian Stu
|                   SA    :    A    :   U   :  D  SD     Q19   I Can Teach Native Am
|                   SA    :    A    :   U   :  D  SD     Q3-R  Have Ability Teach Low SES
|                                                 |
|                                                 |
|             SA  :     A   :   U   :   D    :  SD     Q25   I Can Monitor ESL
|                                                 |
|          SA  :     A   :  U   :   D    :    SD|     Q5    I Can Help Non Eng Speaker
|        SA   :    A   :  U   :  D    :     SD|     Q9-R  Do Learn Strat For Child Engl Learners
|                                                 |
|      SA   :    A   :   U   :  D    :   SD     |     Q13-R I Know Sci Concepts For Children ESL
|                                                 |
|    SA   :    A  :   U   :  D    :   SD        |     Q1    Teach Stu Not Eng
|                                                 |
|                                                 |
| SA    :    A   :   U  :   D    :   SD          |     Q21-R I Can Teach ESL as Non ESL
|------+------+------+------+------+------+------+------|
                           |
              #7        #9               #2              Respondent ID
              82        76               45              Raw Score
```

Figure 3. Most Probable Response Plot for Personal Self-Efficacy.

Note: Items are ordered and spaced vertically from most easy to agree with (top of table) to least easy to agree with (bottom of table). An abbreviated text of each item is provided due to page limitations. The symbol "-R" denotes negatively phrased items whose scores were reversed prior to analysis. The PSE raw scores for three example respondents are presented along the base horizontal line of the figure (respondents #7, #9 and #2. To understand the meaning of the raw score, a vertical line can be drawn upward from any of the students. This line then shows what the predicted response of that particular student should be to each item. This brings immediate visual meaning to the commonly used raw score total for similar scales. The symbol ":" is used to show the boundary from one response category to another. From a probabilistic point of view, respondent #7 would answer "agree" to items 21, 1, and 13, and would have answered "strongly agree" to the remaining survey items. For his/her answers to the 17 PSE items, respondent #7 earned a "raw score" of 82. This type of plot shows what it means to have a score of 82.

```
|---------+---------+---------+---------+---------+---------|     ITEM
|                            SA      :      A   :   U :DSD      Q2    Girls Can Learn Science
|                                                          |
|                                                          |
|                      SA      :      A   :  U :   D  :SD      Q8-R  Girls Capable As Boys
|                                                          |
|                                                          |
|                   SA       :     A   :  U :   D    : SD      Q26   Girls Can Develop In Science
|                                                          |
|                   SA      :     A   :  U  :  D   :  SD      Q20   Girls Have The Ability To Compete Academically
|                  SA      :     A   :  U  :  D   :   SD      Q22-R Children Of Color Can Learn Science
|                 SA      :      A  :  U  :  D   :    SD      Q28-R Girls Have Ability To Learn Science
|                SA       :     A   :  U  :  D   :    SD      Q6-R  Good Teachers Can Help Low SES Students Learn Sci
|                                                          |
|               SA      :      A   : U  :  D    :      SD      Q10   Good Science Teachers Can Help Low SES Student
|                                                          |
|              SA      :     A   :   U :  D   :         SD      Q32   White Child Can Learn As Well As Others
|            SA       :     A   :  U  :  D   :          SD      Q24   Good Sci Teacher Can Help Low SES Students
|            SA       :     A   :  U :  D    :          SD      Q34   ESL Students Can Learn Science
|           SA       :     A   :  U  :  D   :           SD      Q14-R Effective Science Teaching Can Improve Sci
|           SA       :     A   :  U  : D    :           SD      Q16   Children Of Color Can Succeed
|          SA       :     A   :  U  :  D   :            SD      Q18-R ESL Can Succeed In Sci
|          SA      :      A  :  U  :  D   :             SD      Q30-R ESL Students Have The Ability
|         SA       :     A   :  U :  D     :            SD      Q4-R  Native Am Can Learn Sci
|         SA      :     A   :  U  :  D   :              SD      Q12-R Child Of Color Can Learn Sci
|---------+---------+---------+---------+---------+---------|
                    |
                 #2    #9 #7                                       Student ID
                 85     81 76                                      Raw Score
```

Figure 4. Most Probable Response Plot for Outcome Expectancy.

Note: Items are ordered and spaced vertically from most easy to agree with (top of table) to least easy to agree with (bottom of table). An abbreviated text of each item is provided due to page limitations. The symbol "-R" denotes negatively phrased items whose scores were reversed prior to analysis. The OE raw scores for three example respondents are presented along the base horizontal line of the figure (respondents #7, #9 and #2. To understand the meaning of the raw score, a vertical line can be drawn upward from any of the students. This line then shows what the predicted response of that particular student should be to each item. This brings immediate visual meaning to the commonly used raw score total for similar scales. The symbol ":" is used to show the boundary from one response category to another. From a probabilistic point of view, respondent #7 would answer "agree" to items 10, 32, 24, 34, 14, 16, 18, 30, 4 and 12, and would have answered "strongly agree" to the remaining survey items (2,8,26,20,22,28,6). For his/her answers to the OE 17 items, respondent #7 earned a "raw score" of 76. This type of plot shows what it means to have a score of 76.

PSE subscale. For example, the drawn line's points of intersection with response categories for respondent #7 shows that there is the greatest likelihood of an "agree" answer for item 21, a little less of a likelihood of an "agree" answer for item 1, and even less of a likelihood of an "agree" answer for item 13.

The most probable response plots can be used to very quickly bring meaning to a respondent's raw score total on a SEBEST subscale. As in the case of prospective elementary teacher #7, whose selection of rating categories (Strongly Agree, 5; Agree, 4; Uncertain, 3; Disagree, 2; Strongly Disagree, 1) earned an "82" raw score total for the PSE subscale, the plots allow one to see much more meaning in that score. Figure 4 presents similar information for example prospective elementary teachers for the OE subscale.

The SEBEST could be a valuable tool for science teacher educators working in practical and research settings to assess the personal self-efficacy beliefs of prospective elementary teachers with regards to science teaching and learning for diverse learners. Similarly, the SEBEST could be useful to multicultural teacher educators. For example, the SEBEST could be used to help identify if a particular course or program is achieving what it purports with regard to prospective elementary teacher preparation for science teaching and learning for diverse learner populations. Because the construct validity of an instrument is never fully established (Nunnally, 1970), the construct validity of the SEBEST will continue to need to be studied. In the process, the reliability of the SEBEST, including test-retest reliability, should be re-examined. Norming the SEBEST may provide some insights here and will provide additional information on the SEBEST that will be useful to users. Instruments such as the one presented in this paper should be viewed as evolving tools that will help improve the measurement that takes place in science teacher education. We suggest that subsequent

versions of this instrument should work toward including items for use with practicing elementary teachers should be pursued, a project the authors are undertaking.

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Appendix A

Self-Efficacy Beliefs about Equitable Science Teaching (SEBEST)

Directions: Please indicate the degree to which you agree or disagree with each statement below by circling a response.

---

1. I will be able to effectively teach science to children whose first language is not English.

   Strongly Agree Agree Uncertain Disagree Strongly Disagree

2. Girls can learn science if they receive effective science instruction.

   Strongly Agree Agree Uncertain Disagree Strongly Disagree

3. I do not have the ability to teach science to children from economically disadvantaged backgrounds.

   Strongly Agree Agree Uncertain Disagree Strongly Disagree

4. Even when teachers use the most effective science techniques in teaching science, some Native American children cannot achieve in science.

   Strongly Agree Agree Uncertain Disagree Strongly Disagree

5. I can do a great deal as a teacher to increase the science achievement of children who do not speak English as their first language.

   Strongly Agree Agree Uncertain Disagree Strongly Disagree

6. Good teaching cannot help children from low socioeconomic backgrounds achieve in science.

   Strongly Agree Agree Uncertain Disagree Strongly Disagree

7. I will be able to meet the learning needs of children of color when I teach science.

   Strongly Agree Agree Uncertain Disagree Strongly Disagree

8. Girls are not as capable as boys in learning science even when effective instruction is provided.

   Strongly Agree Agree Uncertain Disagree Strongly Disagree

9. I do not know teaching strategies that will help children who are English Language Learners achieve in science.

   Strongly Agree Agree Uncertain Disagree Strongly Disagree

10. Effective science teaching can help children from low socioeconomic backgrounds overcome hurdles to become good science learners.

    Strongly Agree Agree Uncertain Disagree Strongly Disagree

11. I can help girls learn science at the same level as boys.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

12. Even when teachers use the most effective science techniques in teaching science, some children of color cannot achieve in science.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

13. I do not know how to teach science concepts to children who speak English as a second language.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

14. Effective science teaching cannot improve the science achievement of children from impoverished backgrounds.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

15. I will be effective in teaching science in a meaningful way to girls.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

16. Children of color can succeed in science when proven science teaching strategies are employed.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

17. I will have the ability to help children from low socioeconomic backgrounds be successful in science.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

18. Children who speak English as a second language are not able to achieve in science even when the instruction is effective.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

19. I will be able to successfully teach science to Native American children.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

20. Girls have the ability to compete academically with boys in science when they receive quality science instruction.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

21. I will not be able to teach science to children who speak English as a second language as effectively as I will to children who speak English as their first language.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

22. Children of color cannot learn science as well as other children even when effective science teaching instruction is provided.

Strongly Agree Agree Uncertain Disagree Strongly Disagree

23. I cannot help girls learn science at the same level as boys.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

24. A good science teacher can help children from impoverished backgrounds achieve in science at the same level as children from higher socioeconomic backgrounds.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

25. I will be able to effectively monitor the science understanding of children who are English Language Learners.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

26. Girls can develop in science at the same level as boys if they receive science instruction that is effective.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

27. I will not be able to successfully teach science to Asian children.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

28. Girls do not have the ability to learn science as well as boys, even when effective teaching techniques are used.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

29. I will be able to successfully teach science to children of color.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

30. Children who are English Language Learners do not have the ability to be successful in science even when the science instruction is effective.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

31. I will be able to help girls learn science.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

32. White children can learn science as well as other children when effective science teaching is employed.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

33. I will not be able to teach science successfully to White children.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

34. Children who are English Language Learners can be successful in learning science if the teaching is effective.

Strongly Agree   Agree   Uncertain   Disagree   Strongly Disagree

IMPACT OF GLOBAL SCHOOL/UNIVERSITY PARTNERSHIPS ON SCIENCE TEACHER ENHANCEMENT

Jack Hassard, Georgia State University
Julie Weisberg, Agnes Scott College

Statement of the Problem

Telecommunications has had a profound impact on nearly all aspects of human communication. Whereas the Internet was once a forum used exclusively for data exchange among scientists, it has become a primary mode of communication for many ordinary citizens. We bank, we shop, we even make dinner dates with friends across town using personal and corporate home pages and e-mail. This past year one of our daughters conducted her college search and the application process almost exclusively via the Internet. Yet, despite the increasing extent to which direct Internet connections are available in schools (remember President Clinton's 1996 call to get every classroom on the Internet?), teachers have been slow to incorporate the Internet into classroom instruction (Fabos & Young, 1999). One national survey (Becker, 1998) reported that only 6% of teachers had their students collaborate over the Internet during the 1997-98 school year.

Since the early 1990's, we, along with several other groups, have been interested in using the Internet to support collaborative inquiry through the creation of virtual "scientific communities of practice": web sites, bulletin boards, and chat rooms through which students could collaborate with students in classrooms at a distance (in other parts of the US, or in other countries) in the collection and analysis of data related to common environmental problems and issues. We wrote and published a teachers' guide for implementing the Global Thinking Project (Hassard & Weisberg, 1999a), established a web site to support the project (www.gtp.org), and conducted several summer leadership institutes for teachers funded by the Eisenhower program

and the USIA. We have also organized three large-scale exchanges of student and teachers from Georgia and Russia within the context of the Global Thinking Project (Hassard & Weisberg, 1999c). Yet, like other such projects reviewed by Feldman, Konold & Coulter (2000), we have been disappointed that sustained collaborative inquiry has not been maintained between classrooms over time.

Feldman, Konold & Coulter (2000) suggest that network science projects have not realized their initial promise because the focus of these projects is misdirected and because teachers are not adequately prepared for facilitating inquiry-based lessons. According to these authors,

- The Internet should be used to broaden the context of locally grounded science inquiries.
- The teacher's classroom, not the online community, should be considered as the primary learning environment.
- Internet projects must provide multiple entry points for using technology to support curriculum activities, since teachers have diverse attitudes towards and competency with technology, and
- Internet resources (such as informational web sites) should be carefully chosen and integrated into lesson plans that guide students to the most productive use of the resources.

Even teachers who are comfortable using the Internet need to be comfortable participating in scientific inquiry themselves. They need opportunities to develop sufficient content knowledge to respond appropriately to questions and issues that arise during inquiry, and to develop basic skills in the collection, management and interpretation of data. Furthermore, these authors maintain, teachers need to develop these capabilities over time through face-to-face dialog with colleagues in a supportive community of practice.

Purpose

The purpose of the Eco-Connections project was to design a model for teacher enhancement that incorporates cross-cultural interaction and construction of web-based environmental teaching modules, and that would support sustained collaborative inquiry among students and teachers. Over a two-year period, teams of Russian and American teachers participated in summer workshops during which they conducted web-assisted environmental inquiries and designed web-based teaching modules aimed at engaging their students in environmental inquiry and empowering them to take an active role in their communities. The model includes elements such as face-to-face collaboration among teacher-colleagues, hands-on experience for the teachers in data collection and analysis, seminars on advanced topics such as service learning, and ongoing university support.

Background and Theoretical Perspectives

The design of Eco-Connections was based our previous experience with the Global Thinking Project (GTP), and was grounded in humanistic psychology, constructivism, technology education, and service learning. School/university partnerships have been an essential feature of the summer workshops, as well as of the implementation and evaluation of the curriculum materials generated. We begin our discussion with a brief examination of the Global Thinking Project.

Global Thinking Project

Our earlier project, the Global Thinking Project (Hassard and Weisberg, 1992; Hassard, Cross & Plant, 1994), began as an exchange of ideas among American and Russian teachers, teacher-educators, and psychologists about how students learn. A series of unofficial visits of American educators and psychologists to the Soviet Union between 1983 and 1988, sponsored

by the Association for Humanistic Psychology, formed the basis for the relationships from which the Global Thinking Project emerged (Hassard, 1990; Hassard, 1997). Acting out of their common concerns for the well-being of the planet and for improving relationships between the people of their two countries, faculty at Moscow Experimental Gymnasium N. 710 in Moscow, researchers at the Institute for General and Educational Psychology in Moscow and at the College of Education of Georgia State University in Atlanta, and classroom teachers in Georgia eventually agreed to develop collaboratively teaching materials and strategies that would:

1. Empower students and teachers to get involved with important global problems and concerns;
2. Introduce students to collaborative methods and strategies and inquiry that could be used to solve problems locally, and provide the knowledge and technological means need to deal with problems globally; and
3. Develop computer literacy in students that would allow them to use microcomputers as a telecommunications tool to collaborate with counterparts in other nations (Hassard, 1997).

This early collaboration evolved into the *Global Thinking Project* (GTP), a web-assisted environmental inquiry project, supported by a teacher's guide (Hassard & Weisberg, 1999a) and a web site (www.gtp.org), through which students and teachers explore local environmental issues and concerns within a cross-cultural context.

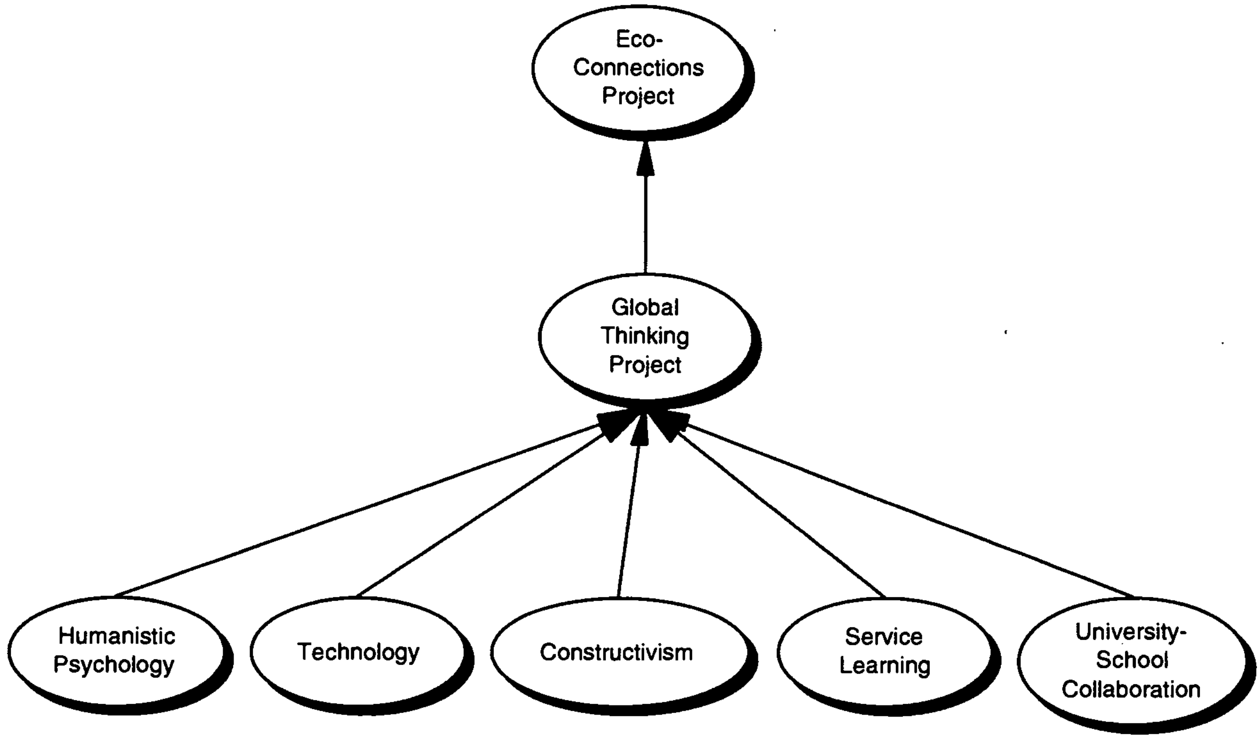

Figure 1: Theoretical Constructs Linking Global Thinking and Eco-Connections Projects

<u>Humanistic Psychology</u>

Our earliest discussions with our Soviet counterparts focused on the role of teachers in creating classroom environments that foster the exchange of ideas within a cross-cultural context. Discussions were held on approaches to creative teaching and the individual development of students, as well on significant social and political issues as nuclear weapons and women's issues. Science education, per se, was not central to our initial discussions. Based on these discussions, we developed the concept of "global thinking, " a concept grounded in a humanistic, rather than a traditional view of teaching and learning. As illustrated in Figure 2, this involves a shift from mechanized, individualistic thinking grounded in an industrial model to thinking that is relativistic, interdependent, and cooperative.

Figure 2. The Paradigm Shift from the Traditional Model to a Humanistic Model

The Traditional Model	Humanistic Model
• Traditional, mechanized thinking • Individualistic--although students may at times work together in groups, interdependence typically is not a goal. • Dependence--teacher-directed instructional model establishes a dependent social system. • Hierarchical---choice-made-for-you. Rarely do students choose content or methodology for their investigations • Emphasis on literacy: knowing facts, skills, concepts • Emphasis on content; acquiring the right body of knowledge • Learning encourages recall, and is analytical and linear	• Innovative, flexible thinking • Cooperative--students work collaboratively in small teams to think and take action together • Interdependence--a synergic system is established in groups within a classroom, and within global communities of practice. • Right-to-choose---students are involved in choice-making including problem and topic selection, as well as solutions; reflects the action processes of grassroots organizations • A new literacy insofar as "knowledge" relates to human needs, the needs of the environment and the social needs of the earth's population and other living species • Emphasis on anticipation and participation; on inquiry, learning how to learn, and how to ask questions • Learning encourages creative thinking, and is holistic and intuitive

This paradigm shift has implications for classrooms and for curriculum in schools. In schools based on the traditional model, teaching and learning are organized around teaching students about specific disciplines. The new model suggests a different way of organizing courses, and experiences. Springer (1993) suggests that:

> Global thinking takes direction from societal concerns rather than from the inward structure of traditional education. Global thinking means looking at the process of schooling differently, considering what it means to be well educated in a global society. Global Thinking presents man as a constructivist, a social scientist capable of using a wide range of scientific attitude skills to develop theories for inventing the future and affecting change. Applying the anticipatory/participation model, global thinking facilitates interactions, connections and partnerships that allow students to experience the social nature of knowledge. (Springer, p.79).

Springer sees global thinking as a means of helping students accommodate to the rapid globalization of the world by becoming aware of and acting on the themes of interdependence and right-to-choose. Interdependence requires action on the part of the student. Understanding

interdependence must go beyond the definition, and be based on real work by the students. Providing experiences in which students learn about interconnections among global problems and among people is essential. Collaborating on cooperative projects with students in other cultures is one example of how to "teach" interdependence.

The “right-to-choose" metaphor has emerged around the world as people have demanded the right to participate in all aspects of their lives. Grassroots movements have had powerful impacts on how people think about change. As people have realized how powerful their images of reality are, they have demanded the right-to-choose. This notion has profound implications for decisions that are made about how and what to teach. Providing students with opportunities to enact their ideas to solve problems, indeed to select the problems they wish to investigate, is a hallmark of global thinking.

Constructivism

The underlying framework for the teacher enhancement program is social constructivism, the notion that learning is a process of active meaning-making in a supportive social context. In teacher education, many of us are incorporating this notion into our courses. Too often, however, professional enhancement for experienced teachers is still based on a positivist, banking model. We believe that like pre-service teacher education, effective learning experiences for professional development should include learning experiences that enable practicing teachers to confront their tacit knowledge about teaching and learning and to build new understandings as they reflect together on common experiences.

This project called for cross-cultural teams of teachers to design web-based environmental science teaching modules based on an inquiry model. Not only were we asking the teachers in this project to learn how to use a new technology effectively, but we were also

asking them to learn how to use an inquiry model in conjunction with the Internet. In practical terms we accepted the notion that the experienced teachers in this project had varying levels of familiarity with inquiry-based teaching and with using the Internet to support science instruction. Since we believe that learners construct new knowledge through direct experience, collaborative discourse and reflection, the summer workshops were designed using an experiential and active learning model to give the participants a common basis for discussions centered on pedagogical theory. The cross-cultural composition of the teams allowed participants to explore each others' unique perspectives regarding environmental problems and issues in each others' countries, and to incorporate their new understandings into topics in which their students would share a common interest.

Service Learning

Service learning is any learning experience in which students learn and develop through active participation in thoughtfully organized service experiences that meet actual community needs. Service learning experiences which are carefully integrated into the academic curriculum prepare students for living and actively participating in a democratic society, allow students to practice newly-acquired skills in an authentic context, and lead to an increased sense of social responsibility and caring for others (Wisenmeyer & Rubba, 1990; Dunkerly-Kolb, 1998). Our previous work has shown that when students engage in such real world collaboration with citizens of other countries to address environmental problems of local concern, they develop enhanced global perspectives as well. (Dunkerly-Kolb & Hassard, 1997; Hassard & Weisberg, 1999b,c) In this project, participants attended a seminar on service learning and then actively incorporated principles of service learning into their web-based teaching modules.

Technology

The development of new technologies has fostered new ways of conceptualizing the teaching of science (Tinker, 1993). One area that received great attention during the 1990's was the use of telecommunications in science teaching to create technology-mediated communities of learning. Projects such as the National Geographic Society KidsNet (Weir, 1992), TERC's Labnet (Ruopp, 1993), and TERC's Global Laboratory (Global Laboratory Project, 1992) used telecomputing and team learning to establish communities of science learners. Since 1989, we have maintained a *Global Thinking Project Community of Practice*, which now includes more than 50 schools in 8 countries. Although the *GTP Community of Practice* began as an e-mail project, it now makes use of a full range of Internet resources including a web site (www.gtp.org), electronic bulletin boards, video conferencing, chat and the use of Internet forms to send and retrieve data.

Rather than seeing technology-mediated distance learning as a means of delivering content, we have designed a program that connects people (students, teachers, scientists) in the common enterprise of global thinking through the exploration of environmental problems and issues (Brunner, 1992). We are more interested in helping students ask questions, probe, and reflect about the environment rather than in delivering content to them. The project has conducted intensive Summer Leadership Institutes where teachers from around the world convene to learn about teaching global thinking, an academic-year implementation and support program in which schools implement the curriculum of the Global Thinking Project (Hassard and Weisberg, 1999a), and an interactive website. Building on our previous work, we are working towards an ongoing global community of teachers and students who develop the knowledge, skills, affect and behavior to achieve environmental literacy.

While telecommunications can provide a structure for collaboration among teachers and students, teachers need experiences which will help them implement such complex projects (Ruopp, 1993). Very few teachers have had experience using telecommunications, and even fewer have integrated distance learning into science teaching (Hunter, 1992). To support the Global Thinking Project, we have maintained a sustained program of teacher education which not only provides the technical training teachers need to master telecommunications technology, but also provides ongoing support as they begin to engage their students in telecommunications-mediated collaborative inquiry projects. This support system was extended in the Eco-Connections project to include direct teacher-authorship of curriculum materials and focused university-based support for collaborating teacher-teams.

University/School Cross Cultural Partnership

Although Georgia State University has been the focal point for the collaboration among American and Russian educators over the past fifteen years, the work has been a partnership among schools, universities and research institutions on both sides. Because this work began without external funding, initial support for the project came from individual American teachers and professors. Over a period of five years (1983 - 1988), these American educators persisted by visiting the USSR each year and established connections with various Soviet institutions (Hassard, 1990). Chief among these connections was the relationship established with the USSR Academy of Pedagogical Sciences. Three years before receiving external funding on the American side, the Soviets supported the financial cost of receiving Americans in Moscow and Leningrad, and provided air fare for the Russian educators that visited Georgia between 1988 and 1993 (Hassard, 1997).

Schools and universities have been conceived as equal partners in the work of both the Global Thinking Project and the Eco-Connections project. Both projects have brought educators from both sides together to develop curriculum, enhance each other's professional development, and promote collaboration. These collaborations have included teacher and student exchanges, summer leadership institutes for teachers, student environmental summits, and individual exchanges, as well as on-line collaboration (Hassard, 1997).

The Model: Eco-Connections

The Eco-Connections Project (www.eco-connections.org) is an international collaboration among teachers and administrators in Walker County, Georgia and St. Petersburg, Russia, Georgia State University (GSU), the State Pedagogical University of St. Petersburg, and the Hydrometerological University of St. Petersburg, Russia. The long range goal of the project is to produce a model of staff development and a telecommunications-based science curriculum that other school systems with Internet access will be able to replicate. During two successive summer workshops, Russian and American teachers collaboratively designed web-based teaching modules for middle and secondary school students. The interdisciplinary modules involve students in local and global scientific investigations, and help students develop the knowledge, skill and affective qualities to take responsible citizenship action on environmental issues. The instructional modules were published on the Internet through the Eco-Connections web site, and were field tested and evaluated by the teacher-authors during the 1999-2000 and 2000-2001 school years. The web site facilitated on-line collaboration among the teachers, their students and experts in the field.

Teacher Enhancement in the Eco-Connections Project

A grant from the Georgia Department of Education supported bringing together four cross-cultural teams of approximately five teachers for summer workshops in 1999 and 2000. In July, 1999, these teachers participated in a teacher enhancement and curriculum development institutes in Chickamauga, Georgia. In order to enhance their knowledge and skill about environmental science and web-based teaching, teachers conducted hands-on scientific investigations and used the Internet and other technologies to analyze and communicate ideas about environmental science topics. They also had extensive training on developing web pages, using the web to find resources on environmental science, and using the web as a tool to enhance student learning in their own classrooms. Finally, each team created one teaching module, consisting of several web-based lessons based on a constructivist model of learning. . During the academic year 1999 - 2000 each teacher team implemented the module they developed, as well as one other module. Teacher-teams collaborated during the implementation phase using Internet chat sessions, on-line bulletin board discussions, and video conferences. Local evaluation sessions were organized by the university partners during spring, 2000. The teacher teams met again in St. Petersburg, Russia in June, 2000, to assess their work and to develop a second set of modules to be field tested during the 2000-2001 academic year.

A detailed work plan for the project is shown in Figure 3.

Figure 3: Eco-Connections Work Plan, 1999 - 2001

Date	Development/Implementation Activities
May, 1999	Initial meeting among American teachers in Walker County, and Russian teachers in St. Petersburg Focus: Introduce Internet communication tools (email, e-group, bulletin board and chat rooms); organize several communication activities from May – July in which American and Russian teachers use the Net tools to discuss issues and develop an "Internet Habit of Mind."
July 8 – July 20, 1999	Summer Institute I and Staff Development Program---in Georgia Focus: Development of the first set of web-based modules for secondary students with a focus on social responsibility. Themes: a) Using the tools of Internet to enhance communication and research; b) Enhancing teachers knowledge of environmental science; c) Understanding how to use low and high technology tools to explore the environment; d) Integrating these themes to develop Web-based modules.
September – December, 1999	Pilot Testing, Phase I Teachers in each Walker County, GA and St. Petersburg, Russia pilot test modules in their classrooms. Each module tested in at least four classrooms (two American and two Russian).
	Pilot Testing Center Meetings and Evaluation Data American and Russian teachers meet under the leadership of project staff to discuss issues and problems related to the pilot testing of the web-based modules. Evaluation data collected.
March – May, 2000	Pilot Testing, Phase II The two remaining modules pilot tested in at least four classrooms. Pilot test center meetings continue and evaluation data continues to be collected.
June, 2000	Summer Institute II and Staff Development Program---in Russia Focus: Evaluation of the Web-based Modules, and the Development of additional Web-Based Modules.
September – December, 2000	Pilot Testing, Phase III Two modules pilot tested, each in at least four classrooms (two American and two Russian).
January – April, 2001	Pilot Testing, Phase IV Two remaining modules pilot tested in at least four classrooms. Pilot test center meetings continue and evaluation data continues to be collected.
May – July, 2001	Evaluation of Implementation Program Project staff will use teacher evaluation data to finalize the web-based modules.
July - September, 2001	Final Evaluation and Report

Results

The Eco-Connections project has

- helped teachers develop the skills to author and carry out web-based activities that engage students in problem solving and action taking with respect to environmental science.
- produced teacher-created content based modules that can be used in different cultures to help students understand their own local environments.
- provided teachers and students with a new set of communication tools utilizing the Internet, including e-mail, electronic bulletin boards, chat rooms, web-based forms to post and retrieve data, and video conferencing.
- contributed to better cross-cultural understanding of by allowing teachers and students to work closely with peers from a different culture,
- made use of a website to facilitate cross-cultural collaboration, and
- addressed values such as caring, honesty, fairness, responsibility and respect for self and others through service learning projects in students' local communities.

The Eco-Connections Project has reached over 1000 students, teachers, parents, and community members by establishing a unique virtual community. The project is impacting the way in which students and teachers in different cultures are working together not only to educate and to inform, but also to empower action-taking on important environmental problems.

Tatiana Gurieva, one of the Russian teachers of the Eco-Connections Project put it this way:

> It is a very important project as it makes connections between people in the World. Also, students see how their decisions can be put in the Internet and how they can be read by other people. It will encourage them in the future for doing things influencing the world. Today it is very important to know how man can influence nature and how we can keep our world from destruction.

The project enables teachers, who for generations were isolated from other classrooms and colleagues, to use the tools of the Internet to link their students and themselves with others who share a common interest in taking responsibility for making the environment safer and more sustainable. These teachers have had a concrete experience using technology that positively benefits their students and their communities. Furthermore, they have worked as professionals at very high levels of performance; as authors of the curriculum as well as implementers, they take their work seriously, and are constantly looking for ways to improve their work. Sandy Weathers, an American teacher commented,

> Kim (my partner at school) and I were constantly comparing data gathering techniques as well as the data that was collected. We discussed ways to improve the labs, what was working and what was not working, things we would like to add to or delete from the module, and the Russian communications. We posted data daily and checked the data from the Russian teams and from the other Americans. I have been communicating with one of my Russian partners about the paper she has written about the project. She says she will send me a copy (hopefully it will be translated!), and she sent the address of the Russian site to which she submitted her paper. I also talked with other American partners several times during the project. We discussed how the other module was going timelines, and communications with the Russians.

For educators like Sandy Weathers and her colleagues in America and Russia, this direct engagement in and responsibility for curriculum development represents a new way of thinking about their professional work. The richness of being involved in cross cultural professional development seminars (the Summer Institutes), implementing global environmental science modules they authored, and being responsible for evaluating and changing the telecommunications curriculum has led to an enhanced view of the role of teachers in curriculum planning and development.

For students, the project has brought equally important benefits. Because the Eco-connections curriculum was implemented within the regular curriculum, students have been

shown how using technology can enlarge their view of content (science, mathematics, social studies and language arts), as well as the world. For the students, communicating with peers in another distant culture provided a sense of inquiry that was new to their experience. Even though many of the students had previous experiences "surfing the Internet", the idea of actually communicating with students in another culture was novel. Jose Jimenez, one of the American teachers noted that, "The students checked the bulletin board every day for messages and gladly posted their results in order to compare with the other participants. The students even enjoyed reading each other's messages."

A group of students in St. Petersburg, Russia reported,

> "We were online in Internet once a week. We read the letters of our peers from Georgia and when we had enough time we tried to answer them. During our work we researched issues about environmental problems and tried to find information on INTERNET in Russian. We put some of our results on the page of our school. It was very interesting to work with INTERNET, and we find skills of such experience very important and useful.

But it was not simply the idea of communicating with peers that was of benefit to the students. The students also experienced an enhanced sense of ecological responsibility:

> We've got better insight into the problems of ecology connected with acid rains. We began to pay attention on these questions in other subjects in school and certainly we feel a better understanding of these concepts now. We are conscious now about it. We are looking for the ways to combat with countered problems.

The Eco-Connections Project has developed a curriculum that benefits not only the teachers, students, and parents that have participated in its development, but every other school around the globe that wishes to utilize the project's resources.

Challenges

Eco-Connections is in its formative stage and faces many challenges similar to those faced by other network science projects.

Access to the Internet within their own classrooms is a significant obstacle for teachers. The project leaders worked with each American and Russian school to ensure that at least one computer with a connection to the Internet was available for the pilot classes. On the Russian side, access to the Internet for some schools was difficult; Internet access was via a dial-up modem connection, resulting in slow access speed. Furthermore, most of the Russian schools had only one computer with Internet access. The project provided funding to support Internet connectivity for each Russian school for the duration of the project.

Access to hands-on materials was also an issue for the Russian teachers. In several instances we had problems simply mailing teaching materials to Russia. Russian Customs officials assessed very large fees for these incoming materials. Our solution was to wire the funds to Russia, and have the Russians purchase the materials locally. For items not available there, we had to plan ahead and send project materials with travelers to Russia.

Another challenge for the leadership team was working with the teachers on the pedagogy that underlies project-based teaching. Project-based learning is by its nature inquiry oriented. Teachers must know how to support student inquiry by encouraging questioning, helping students understand how to monitor and collect data, and extending students' understanding through analysis and interpretation of data. The project facilitated discussions among the American and Russian teachers in an online environment using chat rooms and e-mail discussions, at local meetings during Phases I and II of implementation, and during the Summer Institutes of 1999 and 2000.

Another major difficulty was that of language. This barrier existed in face-to-face meetings at the teacher institutes, but also on the Internet, especially in bulletin board communication. A number of the Russian teachers and educators spoke English, and this was

essential at the summer institutes. The initial website (www.eco-connections.org) was designed in English, but a Russian Mirror was established at the Herzen State Pedagogical University Server (www.emissia.spb.su/wcrip/us/wcrip.htm/).

Finally, time was also a major difficulty that the project had to overcome. Teachers whose teaching calendars were already filled worked hard to find time to integrate the modules into their ongoing curriculum.

Summary

Educators in Georgia have demonstrated, through collaboration with educators not only in Russia, but other countries including Australia, the Czech Republic, and Spain that telecommunications can be used to engage students and teachers in network science activities. However, our experiences support the finding of others that without an inquiry-oriented classroom that puts the emphasis on local environmental research, telecommunications activities may not result in the meeting the goals of the projects.

Teacher enhancement that not only engages teachers in new pedagogies and technologies, but also empowers them to develop curriculum for their students in a supportive, collaborative environment, may promote the type of sustained Internet use we seek.

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LEARNING TOGETHER: A COLLABORATION BETWEEN RESEARCHER AND CLASSROOM TEACHER USING INQUIRY-BASED INSTRUCTION

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University science educators routinely work with local teachers through teaching science methods courses that have field experience components, supervising student teachers, and facilitating workshops for inservice teachers. Do science educators make use of these collaboration opportunities to inform their own knowledge about what really goes on in the elementary science classroom?

This paper presents the case of a collaboration between an elementary teacher (Sharon) and a science education doctoral student (McDonald) making the transition from classroom science teacher to university science educator. The teacher and the graduate student developed this collaboration while planning for the implementation of an inquiry-based unit of instruction on erosion using stream tables. During the planning sessions general conversations took place about how to teach science, how to interact with students, and the teacher's personal background in science. These conversations informed the university researcher about how he could use his own experience as an elementary educator to collaborate with this particular teacher and how he could relate "real world" situations in his science methods courses.

Against a theoretical background about interactions with students, teacher knowledge about science, and how teachers can best implement inquiry-based instruction, this collaboration relates a story about the personal journeys of two science educators who helped one another.

Theoretical Background

Child-Adult Interactions

A teacher or more capable peers can create an environment that enhances a student's conceptual understanding. To be most effective, an adult engaged in joint problem-solving activities with a child needs to keep in mind the learner's own intentions and understanding, and aim slightly higher beyond his/her current level of unassisted performance. Vygotsky (1986) noted that when children are placed under the tutelage of an adult or more capable peer, they could perform at levels higher than were possible when working individually. In constructing this concept of the zone of proximal development (ZPD), Vygotsky concluded that what the child can do in cooperation today, he/she can do alone tomorrow. There are four stages to the interaction within the ZPD. At first, the adult has to perform the whole activity, demonstrating every step in the process until completion is achieved. In the second stage, the child attempts to perform some of the actions for him/herself, with the more capable adult or peer completing the more difficult parts. The adult also monitors the activity as a whole to ensure satisfactory completion of the task. Eventually, in the third stage, the child reaches the point of being able to carry out the whole task without assistance. The fourth stage becomes necessary when the child has not learned to perform the task, or portions of the task, without assistance. A new level is then set for the child and the stages are repeated as necessary, concentrating on the part that the learner did not pick up on the first time.

Hedegaard (1990) examined how the ZPD could be used as a tool for science instruction. In her teaching experiment, she saw that it was possible to have a class function actively as a whole through class dialogue, group work, and task situations. This teaching experiment, which dealt with a unit on the evolution of animals, differed from traditional instruction in that the

students were constantly and deliberately forced to act. Children performed their own research, and this research was connected to guided actions, which led the children to critically evaluate concepts. The impressions of the students were important to finding out why this teaching experiment led to understanding.

Science for All Americans (Rutherford & Ahlgren, 1989) acknowledged that scientific inquiry does not follow a single path that leads scientists to scientific knowledge. Similarly for students, different methods of investigation will allow students valuable input and to have responsibility for their own learning. The *National Science Education Standards* (NSES) (National Research Council, 1996) posit, "inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (p. 31). The publication of an inquiry addendum (National Research Council, 2000) has contributed to this discussion. Teachers should provide opportunities where students are given investigations or guided towards fashioning investigations that are demanding but within their capabilities. Teachers and more capable peers can guide or model for a student key elements of science inquiry.

The teacher plays a key role in teaching using inquiry-based instruction within the ZPD. The NSES (1996) state that in determining the specific science content and activities that make up a curriculum, teachers consider the students who will be learning the science. "Such decisions rely heavily on a teacher's knowledge of students' cognitive potential, developmental level, physical attributes, affective development, and motivation—and how they learn" (p. 31). Dixon-Krauss (1996) stated that the ZPD "is defined by both the child's level of development and the form of instruction, and it can be determined by how the child seeks help, how she uses various aspects of her environment, and how she asks questions. This information enables the

knowledgeable one to tailor instruction for the learner" (p. 61). Thus the teacher uses the ZPD to plan instruction and assessment for students.

The science teacher has been the subject of research that describes the science knowledge needed by teachers to teach inquiry, how teachers feel about teaching inquiry, ways of integrating inquiry with other subjects, and how to manage inquiry in the classroom. The following sections examine the knowledge, beliefs, and role of the teacher as related to inquiry science.

Teacher Knowledge and Beliefs about Science

There have been numerous studies on teacher beliefs, teacher knowledge, and what teachers think about the implementation of national standards. Teachers, whether or not they have a specialized background in science, hold the key to understanding how science is presently working in elementary schools (Lunn & Solomon, 2000). Bennett (1992) and Wragg (1989) found a severe and not unexpected lack in confidence amongst elementary teachers, who placed science among the bottom three subjects that they were required to teach. In these rankings the researchers used teachers' perceived confidence how competent they felt themselves to be in teaching a subject as an indicator of their confidence.

There are other aspects of teaching that also need to be examined when looking into how teachers teach science. Waugh and Godfrey (1993) described the importance ascribed by teachers to their participation, or lack thereof, in curricular decision making. Lunn and Solomon (2000) presented evidence that all but one of the teachers in their study had taken "ownership" of science teaching, building it into their professional self-image. Lunn and Solomon used interviews to gather data on their teacher participants.

Inquiry-Educated Teachers

If children are going to have experiences that will influence their development in science, the teacher must provide such experiences for them and permit the interaction between the children and their environment to take place. Renner and Stafford (1970) described several studies "designed to determine the effectiveness of providing teachers with specific educational experience in inquiry-centered teaching" (p. 56). In comparing these inquiry-educated teachers with traditional teachers, Renner and Stafford (1970) found that:

a) the inquiry educated teachers provided the children significantly more of the essential science experiences than did traditional teachers;
b) recognition and recall questions were recorded a significantly larger proportion of times for the traditional teachers group than for the inquiry educated teachers;
c) analysis and synthesis-type questions were recorded a significantly larger proportion of times for the inquiry-educated teachers group than for the traditional group;
d) comprehension type questions were recorded a significantly larger proportion of times in favor of the traditional teachers group, while demonstration of skill-type questions were higher in proportion of times in favor of the inquiry-educated teachers. (p. 56)

The researchers found that inquiry-educated teachers "encourage pupils to become involved in experiences and find their own answers to problems" (p. 56). Pupils learn how to do this systematically and scientifically if they are given the chance. "Inquiry-educated teachers question more and tell less" (p. 56). In addition, Renner and Stafford (1970) found that "specialized educational experiences in inquiry-centered science teaching encourage a teacher to

become sensitive to children, functionally aware of the purposes of education, and equipped to lead children to learn in all subject areas" (p. 57).

Dobey and Schafer (1984) conducted research that continues the discussion mentioned above. They conducted a study of preservice and inservice elementary teachers to find out their feelings about teaching inquiry science, their questioning strategies, and how their science knowledge affected their science teaching. They relate, "teachers with only knowledge of questions and challenges appear to be threatened, not freed, by their lack of knowledge" (p. 48). They suggest that teacher educators should help prospective teachers acquire a repertoire of strategies for responding when the answer escapes them or is not there.

Renner and Stafford (1970) relate that knowledge does not guarantee success in teaching science.

> If inquiry teaching and learning is to be facilitated, science educators must accept the challenge of helping teachers replace the urge to verbally unload knowledge with the skills of using that knowledge to stimulate children's thinking and conceptual development. Knowledge is not enough. (p. 49)

Their recommendations include helping teachers acquire more of the "science knowledge needed for teaching children" (p. 49). Having gained this knowledge, teachers will develop more confidence in teaching science, will teach more science, and will develop the security necessary for dealing "with the uncertainties of inquiry teaching" (p. 49).

Schibeci and Hickey (2000) related that content alone will not effectively lead to more effective teaching, that general pedagogical skills can lead to science lessons that are more fun for students, and effective science teaching requires a level of comfort with content knowledge to make the science ideas "teachable". In this study I sought to understand the content and pedagogical knowledge of one teacher in order to inform her implementation of inquiry-based instruction.

The inquiry addendum to the National Science Education Standards (2000) reports that teachers need support in order to implement inquiry-based instruction. Support for inquiry teaching and learning must encompass several different elements:

> 1) Understanding what is meant by inquiry-based teaching and learning and knowing the advantages documented for inquiry in research; 2) understanding the change process that occurs when teachers are learning to teach through inquiry and students are learning to learn through inquiry so that all of their concerns can be anticipated and support can be tailored to meet their evolving needs; and 3) providing a coordinated support system that maximizes the staff's opportunity to grow and succeed in teaching through inquiry. (p. 143).

During the course of this study I found out about the kind of support that this classroom teacher received when teaching science in her school.

Role of the Teacher

The role of the teacher is to promote a process of inquiry that will lead to the joy of discovery. Fitzsimmons and Goldhaber (1997) relate that "a process of inquiry that allows and encourages children to raise questions, develop investigation strategies, formulate theories, and report findings" needs to be promoted by the classroom teacher. While children were conducting investigations at a water table, teacher imposed a rule of no *carrying water between the water tables*. Fitzsimmons and Goldhaber (1997) discussed how that this was purposeful on the part of the teacher:

> The teacher's intent was to provoke some degree of cognitive conflict and to encourage all children to design continuous pathways that could transport water. Perspective-taking skills, which include the ability to understand another person's viewpoint as well as the capacity to consider innovative uses of materials, became an integral component. (p. 18)

As a result, children had to work cooperatively, comply with new restrictions, and creatively combine materials. The classroom teacher created all of this.

Teachers can also establish an environment that allows children to communicate the results of their investigations in a variety of ways. The students can either communicate their

findings to a friend or to the teacher. At other times more formal reporting sessions are helpful. The teacher can facilitate this through the organization of the materials. Fitzsimmons and Goldhaber (1997) related that:

> The close proximity of the materials allowed children to discuss and demonstrate their ideas. Group participation during the reporting process encouraged scaffolding to occur. Children at slightly different levels of understanding helped classmates to make connections. (p. 19).

Fitzsimmons and Goldhaber (1997) discussed the role of the teacher as integral to the process of promoting inquiry science in the classroom. "This process is facilitated by teachers who observe, respect, and support children's work" (p. 42). Teachers who value inquiry-based investigations provide "blocks of time over an extended period to encourage in-depth hypothesis building and testing" (p. 42). Teachers can also show that they are active learners who model curiosity, perseverance, and listen to others. Interesting materials that are used in a variety of ways to develop problem-solving abilities are made available in the classroom. Time is provided for children to have group discussions.

Teachers need more than a rich supply of resources and support materials. Books and materials alone do not make learning happen. According to a study by Decker (1999), a broad, detailed instructional plan is the key for effective teaching to occur. Decker recommended the basics of doing, constructing, and connecting:

a) Doing: Learning is something that students do, and not something that is done to them. The students engage in the active doing process through inquiry and hands-on activities.

b) Constructing: Students ask questions, acquire knowledge, and construct explanations of natural phenomena.

c) Connecting: The students test those explanations and eventually connect their ideas and thinking to others. (p. 28)

These three elements are incorporated into the creation of an instructional plan that is a weekly schedule. The schedule runs all year long and Decker relates that it pays tangible dividends in the classroom. "Since implementing this weekly framework, I've noticed that students have better attitudes toward science and a more extensive use of science process skills" (p. 29).

The teacher, therefore, plays an important role in the implementation and promotion of inquiry science in the elementary classroom. Through their knowledge of science teaching, science processes, and science content, teachers can give children the opportunity to construct science knowledge with their guidance. It takes more than just knowledge of science pedagogy and skills to promote inquiry-based science. Teachers need longer periods to give students the opportunity for investigating and sharing their discoveries with the rest of the class.

The information provided by the Benchmarks, NSES, and the inquiry addendum to the NSES, when combined with research in science education, inform science educators about the key components that are needed when teaching inquiry and in science teacher education. Two additional elements, however, are needed. First, science educators need to know what practicing elementary teachers are faced with when they begin to learn how to implement inquiry-based instruction. Second, research from collaborations between science educators and elementary classroom teachers implementing inquiry-based instruction can inform how we instruct other in-service teachers and preservice teachers in methods courses. This study examines both of these elements.

Personal journeys by teachers that involve asking questions about their science and pedagogical knowledge are natural, according to Abell (1999). Abell related an example of a preservice teacher who asked questions during a month long moon study, in a "personal journey toward understanding" (p. 39). Likewise the teacher in this study was on a personal journey

toward understanding how to teach inquiry-based science. The excerpts from the interviews conducted during this study provide some insight into that personal journey.

The research questions that guided this study included: How does a university researcher make the transition from elementary teacher to helping other teachers learn how to teach science effectively? How does an elementary teacher make the transition to teaching science using an inquiry-based approach? How can a university science educator facilitate such a transition?

Research Design

This study was a naturalistic study in that the researcher did not attempt to manipulate the research setting (Patton, 1990). Guba (1978) defined naturalistic inquiry as "a discovery-oriented approach that minimizes investigator manipulation of the study setting and places no prior constraints on what the outcomes of the research will be" (p. 67). This study took place in a local elementary school (near a major university), focused on naturally occurring classroom events since "the point of using qualitative methods is to understand naturally occurring phenomena in their naturally occurring states" (Patton, 1990, p. 41).

The research design was based on a collaboration between the teacher and the university researcher in planning and carrying out an earth science unit. This teacher's fifth grade students were to conduct investigations about specific Earth science concepts. The curriculum was based on one module of the National Science Resources Center/Science and Technology for Children (NSRC/STC) (1997). The module, Land and Water, uses a stream table to illustrate the key concepts contained in erosion. The module was selected to promote students' inquiry learning, i.e., letting students plan and carry out their own investigations. Thus instruction was encouraged an environment of inquiry in the classroom, and promoted children's interactions through small group work. The module took ten to twelve weeks for the class to complete.

The Collaboration

Sharon is a fifth grade teacher at Bohrer Elementary School. Sharon and the site for this study were chosen because the graduate student researcher has collaborated with Bohrer in field experiences associated with the elementary science methods course he teaches. In this experience undergraduate students teach science lessons in the Bohrer teachers' classrooms. Sharon was selected for this study because she uses an inquiry approach to teaching most subjects and has been eager to improve her inquiry teaching skills in the area of science. Sharon has taught for twenty-three years at the same school, at fifth grade for the last ten years.

This collaboration took place during one summer and subsequent semester as Sharon and I planned and implemented an inquiry-based Earth science unit using stream tables as models (NSRC, 1996). This was her first exposure to a kit based science unit and the first time she had used an NSRC/STC module. Sharon had not been pleased with the results of her science instruction using textbooks and limited hands-on materials. She felt as though her instruction was teacher-centered and wanted to move to a more student-centered mode of instruction. Although she had previously hosted elementary science methods students in her and had witnessed the positive effect that inquiry-based science had had on her students, inquiry-science was a new instructional approach for her.

In this study, my role as researcher was that of participant observer (Patton, 1990). I gained access to the site by teaching a section of elementary science methods at Bohrer for three years. As a result of this participation, I have been able to establish credibility and trust with the Bohrer faculty and staff. This prior knowledge of Bohrer Elementary School has provided me with a well-rounded history of their use of science curriculum and instruction. Furthermore, as an elementary teacher for thirteen years, four years in fifth grade, I had implemented inquiry

instruction and served on science materials adoption committees. My master's thesis, dealing with the misconceptions of fifth graders concerning the cause of moon phases, has also provided me with experience in interviewing students and with the culture of fifth grade. This prior experience has helped me to focus on the nuances of student signs in small group work. As a participant researcher, I took the stance of empathetic neutrality (Patton, 1990). "Empathy communicates interest in and caring about people, while neutrality means the researcher is nonjudgmental about what people say and do during data collection" (p. 58). This stance allows the voices of the research participants to be heard.

Data Collection and Analysis

The primary data sources for this study consisted of a journal kept by Sharon while teaching the Land and Water module, and interviews with her both during the summer planning sessions and during the erosion module. Interviews consisted of semi-structured interviews (Bernard, 1995; Patton, 1990) conducted once a month both before and during the erosion module. The planning sessions and interviews with the teacher were recorded. Additional sources of data included field notes during observations, analytic memos, and videotapes of the teacher's fifth grade class working with stream tables.

Data analysis began during data collection through writing analytic memos and reading field notes and interview transcripts. All data sources were organized and coded. After organizing the data and looking for patterns, I built a case analysis (Patton, 1990; Stake, 1994; Yin, 1994) of the collaboration. Finally, I generated assertions from the data, supported with examples from the case analysis.

Results

The teacher's goals in the collaboration were to develop effective cooperative learning skills, and questioning strategies to facilitate learning and interaction with students. The researcher's first goal was to examine the teacher's role attempting to implement inquiry-based instruction. A secondary goal was to examine his own role as an emerging researcher. This collaboration challenged the university researcher and the teacher-researcher to think about and reflect about how they taught science in the classroom. Journal entries for both researchers addressed a number of areas: facilitating inquiry science, questioning strategies, students' science journals, students conducting long term inquiry investigations, and using technology to present their research results.

As a result of the collaboration, both researchers came to identify what they needed to think about during the study.

> Working with an in-service teacher made me examine my own thoughts about teaching science methods to preservice and in-service teachers, as well as what works in an elementary classroom. (Jim, Journal)

> I need to work on my questioning strategies and how to get students to think beyond what is required during a science investigation. (Sharon, Journal)

Collaboration was new to both of these individuals. The university researcher was in the process of learning how to be a science educator. The classroom teacher was learning how to improve her science instruction. The key thing is that they were willing to learn from each other.

I entered a classroom and began to see another teacher's perspective on teaching science. Building on my own prior experience as a science teacher, I added Sharon's perspective in order to better inform my own experience and to build on it. This perspective allowed me to have a better idea of practical tools and vignettes that I could share with my elementary science methods students. Speaking with Sharon on a consistent basis allowed me to have a window into her

thoughts about things that I take for granted. Revisiting these issues and talking with Sharon has made me a better science educator.

The classroom teacher has shared with me that she learned how to be more comfortable teaching science by getting into some of the nuts and bolts behind a particular curriculum. As we talked about particular lessons in the erosion module, she understood how they built upon one another and that it was all right to make certain modifications. She learned to make the lessons more meaningful to students by putting a personal touch into lessons by sharing her own questions and thoughts.

The excerpts that follow are issues that Sharon and I discussed over the course of planning and carrying out the erosion module. These are issues not mentioned in the NSES as seen through the words and impressions of one classroom teacher learning to teach inquiry-based science for the first time.

What the Teacher Hoped to Gain from Teaching the Erosion Module

Sharon made the following comments during the summer before the erosion module was to be taught.

> Personally I would hope that I would learn more about erosion, that's what I would say. I mean, really more in depth, so hopefully when I do it again I will feel more confident when they ask me a question, what to answer or where to send them for help I would think. Hopefully, what I will do after we do these little erosion studies that there are several in there that I like that I would want to do again for the following year. That would be the two things I would think. (Sharon, Interview)

Sharon makes two key points about background knowledge and picking the best lessons to use over again are made before the module has even begun. Throughout the larger study, when her fifth grade students were doing the erosion module, Sharon mentioned which lessons she would use again and which ones she wouldn't. Sharon commented to me that the lessons that she

wanted to use again were those that gave the students the opportunity to plan for and then build structures like dams where they could apply their knowledge of erosion and the stream table. The lessons that she would skip were those that looked at the individual soil components and looking at the sediments being carried in runoff water. She decided that she would make such lessons into teacher demonstrations.

She made similar comments to me again at the end of the four-month study. Thus, these beliefs remained throughout the entire four-month period. Her comments about the lessons also usually included that there needed to be more information about certain background material for the teacher in order for the teacher to know what to tell her students.

Sharon was not completely comfortable with inquiry teaching and did not want to totally give up on teacher-directed science instruction. She wanted to continue using demonstrations and providing the students with content knowledge. This was evident when she had students memorize the parts of a watershed and made comments in students' science journals about using proper terminology. However, Sharon wanted to retain lessons where the students could discover new things about erosion and apply their knowledge, but she wanted to eliminate lessons where students were exploring subconcepts about erosion that were not as exciting (i.e., soil components, examining runoff, and growing vegetation).

Comparing STC Unit to the Textbook

The following comments from Sharon occurred during an interview after the first five lessons of the erosion module. She reflected on the material in the unit and how much preparation was necessary for each lesson.

> I did not realize how much was in it (the erosion module) until I taught it. But just by looking at the material that we are going to be covering. For some reason, I know this doesn't make sense, it doesn't seem as overwhelming as the science book (Silver-Burdett). And why I don't know. Maybe its because it, is maybe

> they are reading, reading on paper and they have got new terms, new terminology, next page they are jumping to something else. Where I think this (the erosion module) will be going a little bit slower. It seems like is connected to the other a little bit more. _I would say there is a lot more hands-on aspect of it in the erosion thing. However, if you look at the science book almost every other page also has some type of activity to do. But we pick and choose. And I do not do probably a fourth of what you could be doing (in the science textbook she is using). (Sharon, Interview)

The key comment here is that she did not find the erosion material overwhelming. She makes an observation that the science textbook is too full of information and that the students are responsible for too much material. This seems to fit with which lessons she wanted to throw out above.

Set up and Clean up of Hands-on Science

Encouraging Sharon to give this inquiry-based material a chance and getting her used to teaching and setting up the material had its difficulties for me as I noted in my journal.

> Oh set up and clean up. I mean . . .think of it that way because you have no matter what grade level you are in. You assume that you should be spending 45 minutes for science. Well, you have a subject to teach before that and a subject to teach after that. So the reality of it is if you would think to be able to set up all of this stuff on a daily basis it is really almost impossible. So when you are doing anything working on a project or science. It is almost like you do it in little sections at a time. So you might say all right. . If I am doing nutrition. I am going to do all of the little science experiments or pick two days a week to do the little science experiments and I will be honest with you, you try to look for the ones that are easiest and not the ones that are the messiest ones to do plus the ones you can do because there is one of you with x amount of kids. (Sharon, Interview)

On the day when students were going to use their stream tables for the first time, the teacher's manual stated that ice packs from the Land and Water kit should be put into the freezer the night before in preparation for modeling the water cycle. When I arrived at the school to help Sharon set up the lesson the soil components (sand, gravel, humus, and clay) were not in the stream tables and the ice packs had not been put into the freezer. There was no sand in the kit

because it was too heavy to ship with the rest of the materials. The water to be used in the water cycle investigation was not in the two-liter bottles

> So when the fifth graders came in Sharon said well the set-up isn't done, there was no sand, she was very frustrated. So there were three students who helped us with putting the humus, clay and gravel (without the sand) into the stream tables. We measured things out, mixed them together and then put the mixture into the buckets so that the groups could have them. I had to go out and buy some ice because the ice packs from the kit were not put into the freezer. I also had to go out and get some Ziploc bags to put the ice in. So I went out and did that at 12:50 and then came back a little after 1:00. The warm water was not in the two-liter bottles, so I quickly filled up the bottles. (Jim, Analytic memo)

> Sharon commented on the same incident during an interview later that day.

> *She said to me after school that, "I am only one person. I know why if one person were doing this by themselves they would not do it.* [This excerpt is from the first day that the students use the stream tables.] (Jim, Analytic memo)

I learned a lot here about the kind of support that Sharon needed to implement the instruction of this unit. Sharon was worried about the set up and clean up of the stream tables and the other materials that the students were using. I remembered how my students had helped me when I taught science, so I suggested that students could lay out the materials in the morning before doing the lessons in the afternoon. Trusting the students to help with the set up and clean up saved Sharon some valuable time and anxiety.

The discussion that resulted also helped the two of us understand the thoughts of one another. Something uncomfortable turned into something very productive for the collaboration between the two educators. I could trust my own experiences as a classroom teacher and use them to suggest things to Sharon. Sharon felt we needed to be more specific in our conversations about the responsibilities that each of us had before a lesson was taught. We checked in with one another at the conclusion of each and every lesson in order to know how to set up for the next lesson in the erosion module.

Other Constraints on Teaching Science

During one of our monthly meetings, Sharon reflected on some of the constraints that she faces when teaching science in the fifth grade.

> I would say the biggest thing would be lack of money. I mean just look at rocks and minerals. To purchase the beautiful displays you would love to have. Get the rocks and everything so they can do the scratch tests. To me it is a matter of money and a lot of it is in science I think it is a lot of work to prepare for science. And it is one subject of many subjects. (Sharon, Interview)

Sharon's comments point out some of her general constraints that have to do with science instruction. The constraints that Sharon identified in this section were money, set up and clean up, and time. These are not items typically mentioned in preservice or inservice preparation courses on science teaching. I learned that I need to mention these and other constraints to my preservice teachers when talking about science instruction. These real world examples can inform preservice teachers about what they will find when they have their own classroom and allow opportunities to discuss the ways to overcome the constraints.

Teacher Interaction with Students

Sharon made some comments her about her interactions with students. I asked her what she expected when she came up to a group and interacted with them during a lesson in science and during the erosion module.

> Everything. I would say everything. I usually just first go around and I will always ask, "Do you understand what you are supposed to be doing?" Then I walk around and I try to see where they are, to make sure they really do understand because it seems that sometimes they don't. And then I might go around and say do you need any help? You know it depends on the group. In general my objective is not for it to be behavioral. My objective is to be there. . .to help them if they need me but to make sure they are staying on task and then if a behavioral problem comes up then you deal with that. But I suppose your hope is you won't have any but you always do. (Sharon, Interview)

The comments above show that Sharon concentrated her interactions on student understanding of the science material and whether they needed help of any kind. Behavioral concerns were something she dealt with if the situation called for it. Sharon also related to me that she tried to keep a lesson moving so that behavioral concerns could be kept to a minimum. Teachers who are switching to an inquiry-based method of science instruction need to expect that their interactions with students are going to change. By having Sharon discuss the interactions that she had with her students, she made the transition to inquiry instruction informed about her role as facilitator and mindful of how those interactions where going to change. This discussion continued for the remainder of our collaboration and was an issue that we frequently revisited.

Students conducted numerous long-term inquiry-based science investigations during the course of the "Land and Water" module. The following journal entry provides Sharon's reflections about the difference in attitude that she noticed in her students:

> The science materials that I was using before would not allow the students to have any input into their science learning. Long-term investigations allowed the students to ask their own questions and determine the direction of their learning. This is not threatening at all! I should have done this before. (Sharon, Interview)

These comments came at the very end of the erosion module. Sharon had seen the some of the value of using an inquiry-based method of science instruction. She could then make a solid comparison between this module and the material she had previously. Long term investigations, as opposed to one shot activities, now had some value for Sharon. Students generated more questions during this module than she was used to using science textbooks. Student input into and responsibility for their own learning in science was a new revelation for Sharon that she planned on emphasizing in the future. Sharon needed a lot of support in order to stick with the entire unit of instruction. Having someone to offer encouragement and suggestions is one of the things that allowed her to learn new things about science instruction.

On the last day of our collaboration, Sharon mentioned that having a support mechanism in place was beneficial when trying out new science materials.

Assessment in Inquiry-based Science

During an interview, Sharon reflected on the new science curriculum that her school had adopted. Sharon reflected on the assessment practices that go along with the adoption of this new material. Sharon had found difficulty with getting enough grades from the erosion unit.

> But there is almost too much information in there (the new curriculum) than all of a sudden, boom, you are doing this you might be reading discussing maybe doing a couple of little worksheets. It is not that worksheets are very, very easy. The little things you do, or collections you do are very easy. But then the tests are ridiculous. So there is not a very good correlation between what they are doing throughout the chapter compared to this test that all of sudden is thrown at them.
>
> It's (tests that come with the book) too big of a leap. Too many arbitrary things that they are picking. What needs to be done is you go you take the test; you mark in the chapter to emphasize what they are going to be tested on. Not to say that even that's what I would be testing on. So I don't use the tests. Or if I use it, I adjust it. (Sharon, Interview)

The "assessments" provided by the publisher of the erosion module were more like a pretest and posttest for alternative conceptions. These assessments did not provide the students with questions about the material, but presented them with the opportunity to look at photographs of different landforms and interpret what they saw and noticed in the pictures. The interpretation of the students did not provide Sharon with anything she could use for grading. Sharon, with my assistance, created some writing prompts for science journals and data sheets for students to record information and draw conclusions. We also asked students at regular intervals how they would define erosion and what they were learning by using the stream table.

Sharon had not previously used science journals to assess her science instruction. She reflected about this in her journal:

> Science journals have given me a much better idea of what students are thinking about and how I can use that information to adjust my own instruction. (Sharon, Journal.)

These excerpts should be interesting to science teacher educators who work with teachers who are worried about how to derive grades—either from an approach to science that is inquiry-based, or from publisher's materials that are too difficult for students. I learned that Sharon needed help in creating her own materials for assessing students. The materials provided by the publisher did not give Sharon enough opportunities for evaluating how her students understood the concepts of erosion. She decided to use the journals we had developed for the study as an opportunity to evaluate and grade her students.

Connections Made by Students Using Inquiry-Based Materials

As the module progressed, Sharon began to see the connections that her students were making by doing inquiry-based science.

> The neat thing about the models (stream tables) was that once they had their set ups and they were in their groups and they placed the dirt in, they placed the warm water to simulate the lake, and they put the plastic wrap over the stream table and then they put the bag of ice on top of that. A fog was created in the stream table and it was hard to observe things but that is also part of the water cycle, which is what they were trying to simulate. So then when the ice over the land they were using hand lenses to look at, it was hard for them to see. One of the interesting things was that they figured out the fine line between tapping on the plastic wrap hard enough to make a hole in it or tapping lightly to get the condensation that had built up on the plastic wrap to simulate rain in their model. They did make some comments about that. (Sharon, Interview)

Sharon made these comments on the same day that she was frustrated about set up and clean up (the first day the stream tables were used). Along with the frustration she felt about not having everything done ahead of time, comes her statement about what the students were noticing on the very first day using the stream tables. Sharon and I soon smoothed out our responsibilities for set up and clean up and her frustrations did not come up again during our

conversations. However, she constantly commented on the connections that her students were making from doing investigations with the stream table. These were the positive aspects of inquiry-based instruction that balanced out the frustrating parts of getting inquiry-based science under way. She commented to me at the end of the collaboration that it was what the students received from this type of instruction that would make her continue to improve her inquiry-based teaching skills.

Discussion

The research questions for this study were: How does a university researcher make the transition from elementary teacher to helping other teachers learn how to teach science effectively? How does an elementary teacher make the transition to teaching science using an inquiry-based approach? How can a university science educator facilitate such a transition? It is appropriate at this point to revisit these three questions.

A university science researcher and educator making the transition from elementary teacher to facilitating inquiry-based instruction for other teachers should not forget his own experience. Engaging in this planning and collaboration helped me recall some key lessons from my own elementary science teaching experience. I had to reflect about these experiences and learn how I could use them to help Sharon plan for her experience of implementing inquiry-based science instruction for the first time. What helped me the most was thinking about the teaching colleagues with whom I worked, the science facilitators at National Science Foundation teacher institutes who helped me feel confident about using inquiry instruction, and the preservice teachers whom I now teach in elementary science methods courses. I did not need to start over in order to help Sharon, I had to get in touch with my own experience and use it to my advantage.

I went through the transition from a classroom teacher with ten years of experience to the role of facilitating someone else to teach inquiry science. My role had changed and I had to adjust.

> I am clear about what motivated me to start teaching inquiry-based science in my classroom and that helped me to connect with what Sharon is going through. At the same time my role has changed and I find myself on the other side, helping Sharon to modify her teaching practices in science. That is an awesome responsibility but a good feeling! (Jim, Journal)

Elementary teachers can make the transition to teaching inquiry-based instruction more easily if they permitted to share their past and current concerns, fears, and constraints with teaching science. Talking through the process of planning her first inquiry unit of instruction helped Sharon to communicate to me how I could best help her. We went through each of the sixteen lessons in the erosion module and discussed questioning strategies, interactions with students, content knowledge, and her role as facilitator. Sharon learned that a colleague is important when doing something new in science for the first time. She held on to some of her previous ideas about teaching science, which is understandable because no one could expect her to completely overhaul her teaching philosophy after one unit of instruction.

A university science educator can help a teacher make the transition to inquiry-based instruction by helping the teacher to gather materials and resources, modify lessons from science materials that have already been adopted, and help set up materials for lessons. Meeting with the teacher on a regular basis, observing the teacher enact instruction of the new science material, and debriefing with the teacher after instruction can make things easier for the classroom teacher by providing necessary support. These meetings can also help the university science educator

inform his own teaching of preservice teachers. Collaboration means working together with each party coming away with a different perspective. Sharon and I both benefited from this exchange.

Regular debriefing during a unit of instruction allows both the classroom teacher and the university researcher to check in with one another. Regular contact was important during our collaboration because both of us could identify issues as well as changes in attitudes. Talking with Sharon on a regular basis provided me with more immediate access to what she was thinking. If a lesson had not turned out a certain way or if the background information provided in the teacher's manual was not extensive enough, we could deal with those situations immediately. Normally I ask my science methods students to reflect on and tell me about how their lessons have gone **after** they are over. Talking with Sharon on a regular basis has made me rethink this practice. I will talk with my preservice teachers while their lessons are going on and have them inform me about what they are thinking **as** they are teaching.

These results provide some evidence that, for this elementary teacher-researcher and university researcher, implementing an inquiry-based science program in the classroom takes time, and requires a change in attitude for the teacher. Reflection plays an important role in bringing about that change. I therefore believe that our experiences can inform other science teacher educators who work with preservice and in-service teachers who are building theories about inquiry-based science instruction.

Implications/Significance

The National Science Education Standards and the addendum on inquiry teaching and learning (National Research Council, 1996, 2000) lay out how to implement inquiry-based instruction in the classroom. This study has shown that more information is needed in the following areas:

1. More evidence from classroom practice can help university science educators stay in touch with classroom realities and relate their previous experience as science teachers to preservice and inservice teacher education. I benefited from observing and getting to know the concerns of an elementary classroom teacher over a six-month period of time. It helped me to use my own experience as an elementary teacher to help a teacher colleague learning how to teach science in a different way. This collaboration helped me learn to become a better science educator and gave me some valuable experience that I can use in future collaborations and in my preservice science teacher education courses.
2. **More real world information concerning the "growing pains" of implementing inquiry, how to translate the standards into practice, is needed to effectively implement the NSES and Benchmarks. Are the NSES and the NSES inquiry addendum being put into practice? What support do elementary teachers receive when they teach inquiry–based science?** The NSES and the inquiry addendum include vignettes of teachers who have learned to teach using an inquiry approach to science. These vignettes tell about teachers who learned to do this successfully. More information needs to be provided about other teachers who have struggled to implement inquiry-based science in their classrooms because of constraints including time, money, and inappropriate materials. The National Science Education Standards as well as the Benchmarks do no deal with how to use existing material from publishers and how to make them better. The comments of teachers like Sharon need to be heard and integrated into the discussion.

3. **The thoughts of particular teachers in the field and how they can personally inform researchers. How does this real world information impact how we instruct preservice teachers in elementary science methods courses and inservice teachers in workshops?** Most

science educators work with teachers at local schools with their methods courses, with student teacher supervision, or on research done in classrooms with elementary students. These relationships can be developed to the point where science educators can obtain real answers from "real teachers", not just the ones who seem to be the cream of the crop mentioned in the local, state, and national standards and benchmarks. Examples from real teachers can supplement the instruction in methods courses. Preservice teachers can learn what the average teacher faces when they have to begin teaching inquiry-based science. It also provides another perspective for undergraduates besides that of the instructor. This valuable information can be used in our classes with preservice teachers and when science educators are called on to support the adoption of new science materials every six to seven years. Quotes from interviews and the journals of classroom teachers can provide very valuable information. That is often overlooked by university science educators.

This paper presented the thoughts of an elementary teacher with twenty years experience as she took a journey toward becoming an inquiry-based teacher and the journey of a university researcher with 10 years of classroom science teaching experience becoming a researcher. These journeys should help us understand that implementing inquiry-based science instruction takes time and that teachers have certain feelings about how they teach science. This collaboration between a classroom teacher and a university researcher took place over the period of six months when the researcher collaborated with a teacher to prepare for and teach an erosion module using stream tables. In the context of this larger study, a relationship between the two developed where they began to help one other. The classroom teacher helped the university researcher to understand the way she felt about implementing a science approach with which she was not familiar. The university researcher observed her instruction and helped her to prepare for the

instruction of a sixteen-lesson module on erosion and providing the materials necessary for the unit. We believe our experiences can inform others engaged in similar journeys.

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WHAT IS NECESSARY TO INCLUDE IN A SCIENCE METHODS COURSE FOR TEACHERS ON EMERGENCY PERMITS? - THE ROLE OF THE FEEDBACK PORTFOLIO

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In a period of dramatic changes in the area of science education it is necessary to take dramatic measures to improve the readiness of the teachers to employ teaching techniques that are consistent with the reform movement. Various major publications such as the National Science Education Standards (National Research Council, 1996) recommend that science should be taught in the same way that it is constructed – using inquiry. During inquiries, students ask questions and plan ways to answer them, collect, organize, and represent data to create knowledge, and then test the reliability of the generated knowledge. During this process, students learn to cope with difficulties and react to constructive criticism provided by the teacher and peers. As a result, students re-examine their research and decide if more data needs to be collected in order to enhance the generalizability of their findings. Despite these recommendations, in many secondary science classrooms science is still taught mainly using textbooks (Moscovici, 2000).

Shulman (1986) defines professional growth in three major areas: content knowledge (e.g., biology, chemistry, earth science), pedagogical knowledge (knowledge about how to better teach a specific subject or having a variety of techniques at the tip of one's fingers), and curricular knowledge (knowing about curricular resources and how to use them). As the requirements for secondary science teachers increase, so do the topics of the secondary methods courses. Anderson & Mitchener (1994) describe the science methods course as the bridge between the various areas of study, a place where prospective teachers integrate the various kinds of knowledge and apply it in a classroom with students or with peers.

Another area of importance in the secondary science methods courses is the reflective nature of knowledge integration. Schoen (1987) recognizes reflection as an essential tool in all professions (1986), while Nichols, Tippins, & Wieseman (1997), Howe & Nichols (2001), and Koballa & Tippins (2000) suggest using open and closed case studies as tools for reflection and professional growth in science education.

This study looks at another reflective tool – the feedback portfolio developed by students. This portfolio preparation required students to reflect and select their best five learning experiences during the course (or connected to the course, such as the implementation of one lesson in their own classrooms) and provide a short explanation regarding the value of the experience. The feedback portfolio serves two goals: (1) as an assessment tool for the various experiences in the secondary science methods course and (2) as a feedback mechanism for the instructor. Students in the secondary science methods course were required to create a feedback portfolio.

Pre-in-service population – Emergency Permit Teachers (EPTs)

A special quality of this study is that it involves emergency permit teachers. Emergency permits are allocated to practicing pre-service teachers that are in the process of completing their credentials. This category (emergency permits) emerged as the need for teachers in certain urban areas of the United States (such as New York, Chicago, Los Angeles, Las Vegas) exceeded the availability of qualified teachers. Teachers working on emergency permits are required by the school district where they teach to complete their certification requirements in a certain number of years (five years in the State of California) with a minimum of six semester units per year.

Emergency permit teachers are unique because they are at the same time pre-service (they do not have their teacher credential yet), and in-service (they teach during the day in their

own classrooms). Their particular position requires science methods courses with unique features in order to satisfy their needs.

<u>The Secondary Science Methods Course – Student Population Profile</u>

As mentioned previously, the majority of the students enrolled in the secondary science methods courses are teachers working on emergency permits (between 87-95% over the last two years). They teach during the day in their own classrooms while in the evenings they enroll in teacher education classes (and sometimes additional content classes) in order to finish their credentials. It is interesting to point out that although some of these students (about 10-15% for the last two years) began the teaching credential program as "traditional students" intending to go through student teaching with a mentor teacher, they are finishing the program as EPTs.

Student population in the Secondary Science Methods course is compiled of about 50% minorities, with a relative large proportion of Hispanic and African-American students. On many occasions, science EPTs, especially from the minority groups, return to teach in the area where they grew up and become colleagues with their previous teachers. They know and understand the school context and, at the same time, receive support and advice from their colleagues and administration. These two elements are critical for beginning teachers' success, especially for those ones belonging to the EPT category.

The average age for the EPTs enrolled in the secondary science methods is higher than the average in other programs over the country that do not serve EPTs. The age average is about 29-35, with the range between 25 and almost 70 years of age. Most EPTs come to the science methods course after a number of careers, with a number showing up after retiring from one, or even two previous careers. They have experience as professionals and have experienced success in other fields (such as medicine, army, engineering, even teaching at the university level in a

science department). They come into the credential program possessing Bachelor degrees, MSc. Degrees, Ph.D. degrees, degrees in engineering, etc. Their knowledge and previous experiences are strong assets to work with in the secondary science methods course, and they learn to use their previous experiences during their teaching.

Theoretical Underpinnings

This study finds its roots in constructivism, according to which learning is a social process of making sense of experiences in terms of extant knowledge (Glasersfeld, 1989, Tobin, Tippins, and Gallard, 1994). The learning experience needs to be perceived as relevant by the learner, in this case, teachers working on emergency permits and enrolling in credential programs to obtain a teaching credential.

Another theoretical dimension of this study comes from the area of critical pedagogy (Giroux & Simon, 1989). According to Giroux and Simon (1989), teachers are defined as transformative individuals if they respond professionally to content challenges, as well as challenges directed to social norms. In other words, such teachers applaud individuals that fight oppression of any kind (Freire, 1990).

The idea of integrating social constructivism with critical theory is essential for this study. It encourages emergency permit teachers enrolled in the secondary science methods to reflect and understand the experiences that proved to be extremely important for their development, while, at then same time encourages them to feel empowered to say what they think.

Design and Procedures

This study compiles data from four sections of secondary science methods courses taught during the past two years, with each section having between 15 and 25 students. The study is

interpretive (Gallagher, 1991; Erickson, 1986; Eisner & Peshkin, 1990). Data for the analyses was developed from feedback portfolios, other writings such as personal theory for teaching, and informal interviews. Multiple member checks with participants and with individuals that were not directly connected to the study (and who served as non-stakeholdres - Guba & Lincoln, 1989), as well as the use of triangulation (the process of contrasting data obtained using various techniques - Berg, 1989) added to the validity of the results presented below.

From Portfolio to Feedback Portfolio

There is a vast literature regarding the use of portfolio in the assessment process (Collins, 1992; Doran, Chan, & Tamir, 1998). Portfolios proved to have the advantage of "containing several samples of students' work assembled in a purposeful manner" (Herman, Aschbacher, & Winters, 1992, p. 120). Collins (1990), a very well known scholar and researcher in the area of alternative assessments, defined portfolio as a "container of evidence of someone's knowledge, skills, and dispositions." I found it essential to take in consideration also the "disposition," meaning a "sensitivity for a particular type of intelligence" (Silver, Strong, & Perini, 2000). This way, each learner has the opportunity to learn and provide evidence for learning in her own way, according to her particular disposition(s) (using the multiple intelligences and learning styles as referents).

Collins' (1992) developed a list of questions regarding categories of purpose, structure, and authenticity of the portfolio. These questions need to be answered prior to assigning portfolios. After the portfolio is handed in, "the evidence in the portfolio is used to make judgements about the quality of the performance of the person who developed it" (Collins, 1990, p. 159). The advantage with the portfolio is that the collection of evidence is spread over a period

of time showing progress and growth. The teacher can also provide feedback and suggestions during the preparation period (Fong, 1988).

More recent work on portfolios suggest the possibility to use them as reflective tools for the teacher as well as for the student (McMillan, 2001). After determining its purpose, its physical structure, and the sources for its content (Collins, 1992), the portfolio becomes the base for discussions between the teacher and the student, as well as an instrument for reflection (McMillan, 2001, p. 239). Portfolios are also used for determining teacher's progress and professional growth (Danielson & McGreal, 2000, National Board for Teacher Certification).

The feedback portfolio used in this study required the students enrolled in the secondary science methods class to reflect on their experiences in class or connected to class (such as implementing a science lesson observed during the science methods course in the secondary science classroom (6-12th grade). The class assignment required them to select the five best experiences and discuss their importance. Grading rubrics concentrated around the quality of the discussion/argument provided for each one of the experiences.

The Secondary Science Methods Course – Experiences Provided

During the secondary science methods course, emergency permit teachers (EPTs) get involved in a series of experiences addressing the three categories of knowledge necessary for teacher's professional growth – content, pedagogy, and pedagogical content – Shulman (1986). Table 1 summarizes these class experiences, while Table 2 provides a detailed list of the category of "Concepts addressed in class" found in Table 1.

While most of the experiences (unit plan preparation and poster presentation, development and presentation of inquiry labs, concepts addressed in class, etc…) engage students in all three dimensions of knowledge present in Shulman's framework for professional

growth (1986), a few experiences concentrate on one or two dimensions (e.g., development of the case study, classroom environment). It is important to underline the fact that although in most cases the EPTs fulfilled their content requirements, I placed a strong emphasis on content development and content knowledge (in the way used by Shulman, 1986) in the course. In their laboratories, as well as in their unit plan, EPTs were required to develop their content in a way that it will satisfy a non-science substitute teacher.

Table 1 – A summary of EPTs main experiences in the secondary science methods course

Experience	Content Knowledge	Pedagogical Knowledge	Pedagogical/Content Knowledge
Preparing unit plan (use of 6 texts, 6 Internet sites, 2 experts & 2 peers)	√	√	√
Presenting unit using poster presentation format	√	√	√
Preparing and presenting inquiry laboratories which include data collection and interpretation	√	√	√
Developing theoretical framework for teaching science (includes 3 references)		√	√
Visit to the Challenger Center (use of NASA simulations)	√	√	√
Developing a case study on how a student unlike them learns science		√	√
Concepts addressed in class (see Table 2 for details)	√	√	√
Classroom environment based on trust and respect		√	
Building a spread sheet with the 10 best Internet sites on a science topic	√	√	√

Table 2 – A detailed list of subcategories of the category "Concepts addressed in class" (Table 1)

Experience	Content Knowledge	Pedagogical Knowledge	Pedagogical/Content Knowledge
Science classroom learning environments and learning	√	√	√
Reading and discussing National Science Education Standards & California Science Standards		√	√
Reacting to readings in class (inquiry, alternative assessment strategies, constructivism, teacher's growth, safety issues in science labs) using practical examples	√	√	√
Discussing invitations to inquiry presented by the instructor	√	√	√
Discussing power relationships in the science classrooms and their effect on learning		√	
Reacting to a guest speaker talking about integrated science and thematic teaching	√	√	√
Use of Casio probe collectors and graphic calculators during laboratory experiences			√
Belonging to science organizations and getting involved in professional development	√	√	√
Sharing resources	√		√
Reflecting on reflective practice and action research	√	√	
Application of topics experienced in the course at the 6-12th grade level	√	√	√

During the two years, and responding to students needs, I made various changes in the requirements of the course. For example, during the second semester I required each student in

class to perform in class five laboratories, and write ten laboratory lesson plans. The requirement came as a response to the students' lack of laboratory preparation dexterity perceived during the first semester of the study, as well as from personal visitations during field experience and observations in secondary science classrooms. Although the increased number of laboratories proved to be effective in developing students' dexterity and comfort with planning, implementing, and discussing laboratory experiences, during the third semester I requested only three laboratories in order to increase the quality of discussions following the laboratory. Due to larger number of students, during the fourth semester of the study, the number of required labs decreased to two.

Another change I made was to move from reading journals on three occasions during the first semester of this four-semester study, to reading a "philosophy of teaching science" paper that incorporated journal writings and professional literature. The reason I had to give up reading journals was the large amount of time it took to read and respond to students' writings and questions.

Other changes such as the classroom for the meetings, and available materials, and equipment fluctuated during the course of the two years in a less intended way. Classrooms are assigned according to availability, and there are no laboratories that belong to our department. For semester #2 & #3 of this study (see Table 3) I was lucky to be able to use a chemistry laboratory. The laboratory was not available for the other two semesters. Table 3 presents the summaries of curricular preferences organized from the most to the least according to the firstt semester of this study. Percentages represent how many students voted for the experience from the whole class.

<u>Findings</u>

Findings show that students appreciated the different experiences explored during the secondary science methods course. They even appreciated the opportunity to reflect and develop the feedback portfolio. Here is how one of them expressed this idea:

> *The portfolio has given me the chance to think about what each assignment has meant to me. I have never sat down to search out assignments I have completed in order to consider what I had learned from the assignment. In most cases, the assignments I complete for a class go in a folder to be never seen again. This portfolio forces students (me) to look and review what was done, and finally, it requires us (me) to explain the significance of each assignment. Which in turn makes students (me) to work harder on the work they produce throughout the course. A-ha! So, this was your intention from the beginning. Tricky, tricky...*
>
> *By all means this course was one of the most difficult courses for me. Not because of the work, but because you forced me to really think about and reflect on the content of the course. Who would have imagined that a graduate student would find "really thinking" and "reflecting" so difficult? I thank you not for the five best, but the best learning opportunity!* (L.Ch., F00)

It is also interesting to add that a few of my students already employed the feedback portfolio as an assessment tool in their own classrooms. They were delighted with the results as their students learned to provide comments and suggestions that helped the EPTs modify their curriculum and increase learning in their classrooms.

Looking at the results summarized in Table 3, and since EPTs are required to teach every day in their own classrooms, it is not surprising to find that they appreciated assignments with immediate translation into their practice. The large category of "Concepts addressed in class," the laboratories that the EPTs prepared and showed in class, and the unit preparation were at the top of their list.

Table 3 – Summary of the curricular preferences as expressed by secondary science EPTs.

Experience	Semester #1	Semester #2	Semester #3	Semester #4
Concepts addressed in class (see Table 2 for details)	87.5	53.0	86.0	92.0
Preparing and presenting inquiry laboratories which include data collection and interpretation	81.0	100.0	86.0	76.0
Building a spreadsheet with the 10 best Internet sites on a science topic	44.0	53.0	57.0	40.0
Preparing unit plan (use of 6 texts, 6 Internet sites, 2 experts & 2 peers)	37.0	27.0	79.0	76.0
Developing a case study on how a student unlike them learns science	31.0	33.0	14.0	48.0
Visit to the Challenger Learning Center (NASA simulator)	NA	33.0	21.0	36.0
Developing theoretical framework for teaching science (includes 3 references)	NA	7.0	21.0	13.0
Classroom environment based on trust and respect	25.0	27.0	29.0	13.0
Presenting unit using poster presentation format	NA	7.0	29.0	12.0

Concepts Addressed in Class Category

The main attractions in this category were the following: the issue of inquiry science versus activitymania (Moscovici & Nelson, 1998) and the four-stage model for moving toward inquiry science (Moscovici, 2000), alternative assessment strategies (Moscovici & Gilmer, 1996) and differences between assessment, evaluation, and grading as applied in the secondary science classroom, the effect of misuse of power on students' learning (Moscovici, 1998; Moscovici, in press), and using action research to improve practices. Readings, explanations, and discussions on constructivism (epistemology versus methodology) increased students' knowledge on the subject and their capability to chose and employ methodology according to professional goals.

It was important to address these topics in class and engage participants in lengthy discussions with examples. Such a process helped them move towards inquiry science, understand and employ effective alternative assessment strategies at the secondary level, and be able to document one aspect of their teaching and make decisions based on teaching goals and collected data (rather than react to one vocal or disruptive student). In the following paragraphs I will concentrate on the top four experiences, as these are commonly found in science methods courses. The other experiences, such as encouraging a supportive atmosphere based on trust and respect, learning about how students that are different from you learn science, and developing a theoretical framework for teaching science are dimensions that seldom receive central attention. Poster presentations of units began as a way to help visualize the flow of the unit during the science unit presentations. During the fourth semester of this study, posters were placed around the room and EPTs had the choice to go to the posters that they were interested in and discussed details with the poster (unit) producer.

Preparing and Presenting Inquiry Laboratories in Class

This was an essential experience for EPTs. They left the classroom every night with lots of laboratory experiences, ideas that found their way into the secondary science classrooms on the following day. I am very fortunate to work with EPTs as they tend to implement immediately class laboratories and ideas, and report back with results from the field (secondary science classes) during the following science methods session. Such quick turnover is only possible with EPTs or practicing teachers in a workshop situation. A comprehensive folder with laboratory experiences from class is placed on reserve in the Teacher Education Department for the use of our students.

Building the Spreadsheet with 10 Best Internet Sites and Email the Assignment Using Attachments

As not all the students are comfortable with computers, with email, and with the Internet, I decided to introduce such an experience into the course. During the first semester of the study I allocated two class sessions to that experience. As some of the students were comfortable with the computer applications, as well as with the Internet, I decided to reduce the number of sessions to only one and continue to support individual EPTs according to their individual needs. Due to this assignment, EPTs realize that they do not need to invent laboratories for every concept they want to address in their classes. Lots of laboratories, simulations, content sites, are already available for teachers to modify and use in their classrooms. Some EPTs get into professional groups, chats with colleagues, and learn to use email for their professional growth.

Preparing a Unit Plan (including 6 texts, 6 Internet sites, 2 experts and 2 peers)

Preparing a teaching unit required EPTs to use resources, the Internet, and people they know in order to organize three weeks of instruction. Beginning with a concept map (or another visual organizer), EPTs explored the topics they want to address, organized it, and correlated developed curriculum to the science standards (for California or for the specific district). The three-week curriculum also required two laboratories, one of them including data collection (at least six points), data processing, visual representation, and interpretation. In a way, it is the culminating act of the course that integrates all the various experiences provided during the course. The advantage of working with EPTs, again, is that they immediately use everything they can in their own classrooms. It is not unusual to have poster presentations of the three-week unit that include work from the students in the secondary science classroom (6-12th grade) – just the opposite. In most cases, EPTs are able to describe the effect of teaching their unit in the

secondary science class, and the modifications that they are going to make in the future. Like with the inquiry laboratories, EPTs are encouraged to leave a copy of their units in the Teacher Education Department for the secondary science students of the following semesters. They learn that gathering ideas from others in the process of creation is not cheating, but good use of available materials and resources.

Implications

Teachers working on emergency permits (EPTs) are different from the usual student-teacher population where participants have the time to build part of their resources prior to entering the classroom. They are also different from the teachers coming for enrichment during in-service workshops or courses. Findings show that in order to prepare science EPTs we need to provide experiences with immediate translation into the secondary science classroom. This way they are interested to participate as they find the experience relevant to their teaching.

As the goal of the science education reform is to infuse science in the secondary science classroom using inquiry (National Research Council, 1996), we need to emphasize inquiry laboratories and how to modify available resources during the science methods course. Learning about the difference between activity and inquiry (Moscovici & Nelson, 1998) helps EPTs with their work of developing thinkers in their secondary science classes rather than technicians (Moscovici, 1998).

Shulman's (1986) framework regarding the three categories of knowledge essential for professional teachers (content, pedagogy, and pedagogical content) provides us with an elegant tool to structure experiences. Experiences that address these categories are welcome, and, with EPTs, have the potential for immediate translation into the secondary science classrooms.

Lastly, but not last, none of the above-described experiences would succeed if the EPTs did not have time for reflection in and on-action (Schoen, 1987) during the secondary science methods class. EPTs reflected during in-class discussions, while preparing homework assignments (such as the feedback portfolio, reaction to an experience in class, reaction to content standards, etc…) and when they used case studies (as an assignment such as developing a case study, or using case studies from the literature – e.g., Koballa & Tippins, 2000)

In conclusion, it is important to design a secondary science methods course that takes into consideration the student population and makes the experiences relevant and useful for beginning teachers. Such a curriculum has the potential to help reach the goals of the science education reform. The feedback portfolio described in this study proved to be an excellent tool that helps us (as course instructors) make the right choices (right for our student population).

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JUMPING ONTO THE PORTFOLIO BANDWAGON: WHAT TEACHERS SAY ABOUT THE PROCESS

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Portfolios have been advocated as an effective means for encouraging critical reflection (Yost, Sentener, & Forlenza-Bailey, 2000) and as a tool for demonstrating teaching and philosophical beliefs (Borko, Michalic, Timmons, & Siddle, 1997). Portfolios are playing an increasingly important role as assessment tools in education. Science teachers are not only expected to know about the use of portfolios as assessment tools for their students, but portfolios may also be used as one means to assess the professional competence of teachers. For example, teaching portfolios are part of the assessment system for teachers who seek National Board Certification (NBPTS, 1994; Barringer, 1993). Officials of the National Council for the Accreditation of Teacher Education (NCATE) have indicated that portfolios will be increasingly important as evidence of student learning and performance (Elliott, 1998). Additionally, Connecticut uses teaching portfolios as part of mandated licensure requirements (Lomask, Seroussi, Budzinski, 1997). As teacher educators strive to prepare teachers of the 21st century, they must seek ways to help teachers experience the assessment strategies they will be using with their own students.

Well-designed portfolios represent contextualized learning that requires complex thinking and effective communication skills. The portfolio process allows education students to continually assess their professional growth and progress (Wade & Yarbrough, 1996; McCombs & Lauer, 1997). The portfolio product provides the student with organized evidence of his/her work over time. The use of portfolios and performance assessments hold promise for being

stronger predictors of teaching performance than current teaching assessment measures and have important implications for the assessment of beginning teachers (Valli & Rennert-Ariev, 2000).

Many researchers have called for a broadened and integrated view of assessment and instruction that better reflects a conceptual change or constructivist paradigm for education (Duschl & Gitomer, 1991; Barton & Collins, 1993; Collins, 1992; Angelo, 1995). Researchers have also documented a "dearth of empirical research" on portfolios (Herman & Winters, 1994; Wade and Yarbrough, 1996). Herman and Winters found that of 89 entries on portfolio assessment topics found in the literature, only seven articles either reported technical data or employed accepted research methods. Wade and Yarbrough (1996) determined that only a small number of the books and articles on portfolios specifically address the use of portfolios in teacher education. Many of the portfolio studies recently reported focus on large scale, national programs such as the work of the National Board for Professional Teaching Standards (NBPTS) or the Interstate New Teacher Assessment and Support Consortium (INTASC), rather than on the efforts of teacher education programs in institutions of higher education. If institutions of higher education are to place increased emphasis on portfolio assessment, potential benefits and outcomes must be well documented across a range of different kinds of programs.

Teacher educators have reported that well-constructed portfolios may help to capture the complexities of learning, teaching, and learning to teach when used as assessment tools within courses and programs in Colleges of Education (Carroll, Potthoff, & Huber, 1996; Krause, 1996; McLaughlin & Vogt, 1996; Stahle & Mitchell, 1993; McKinney, Perkins & Jones, 1995). There has been a call for teacher educators to develop programs that encourage students to reflect and learn the skills that reflective practice requires (Richert, 1990). The creation and development of portfolios can help to focus reflective practice. Furthermore, the portfolio process can help to

provide information to faculty about program components and their effectiveness as they consider changes and improvements.

One of the most critical aspects of the portfolio process is defining exactly what outcomes or goals the portfolio will address. When an entire program is considered, it is important to work from an agreed-upon philosophical base of beliefs about what the students should know and be able to do as a result of participating in the program. Students from two different institutions participated in this study. At each institution, prior to implementation of the portfolio program, the faculty had developed a list of agreed upon goals. Although the goals differed in number and phrasing, both sets of goals were aligned with current state standards. For example, one set of goals state that students should be able to:

- Demonstrate knowledge and understanding of a common core of knowledge and evidence skill in the use of this knowledge.
- Demonstrate skills to assume responsibility for classroom teaching and/or administration.
- Demonstrate respect and value for human diversity and the ability to work with others to meet the needs of diverse populations.
- Demonstrate an ability to use information technology to enhance student, staff, and personal learning and productivity.
- Use research, practice, and assessment to evaluate and improve student learning and personal professional performance.
- Articulate a personal conceptual framework or philosophy based on research, best practice, and reflection of current educational issues.
- Evidence a disposition to continue personal professional growth and to make on-going contributions to their profession.

This research is an extension of an ongoing research on the development of professional teaching portfolios for the purposes of increased student reflection and as a source of information for program improvement (Stein, 1999; 1998;1997).

Method

This study investigated the impact of implementing a portfolio assessment process on student reflection, student understanding of program goals, and using this assessment information for the purpose of program review. This study involved two samples: pre-service teachers from an institution which had developed and refined its' portfolio process over the past decade and; graduate students in the Masters of Education program at an institution that had just begun to require that students develop portfolios for program completion.

Data was collected during the 1999-2000 academic year and included student responses to an open-ended questionnaire that targeted key aspects of the portfolio process. At one institution, students were well aware of the portfolio requirement and had been working on their portfolios since their entry into the program. These students had opportunities for peer sharing, attendance at Portfolio Open Houses to see samples, and seminar courses associated with field work during which they received information on portfolios.

At the other institution, portfolios were a recent requirement. This sample consisted of students who completed portfolios for their final course in the Masters of Education program in Curriculum, Instruction, and Leadership. While some faculty had used portfolios and portfolio assignments in graduate courses, developing a portfolio was a new requirement for students completing the program. The portfolio requirement, the programmatic goals that the portfolios were to address, and examples of artifacts that could provide evidence of attainment of these goals were describe to students during the first two weeks of the final semester. Because this

was a new requirement for students, examples of professional portfolios from prior semesters were not available as models for students to consider. However, examples of web based portfolios created by students from other institutions were presented.

After students had completed their portfolios for the purpose of course and program requirements, they left their portfolios for a more in-depth analysis by the researchers. Students completed a consent form to allow their portfolios to be used for the research study. Students were also be asked to complete an anonymous, open-ended questionnaire comprised of the following five items:

1. How did the portfolio process impact your understanding of the goals outlined for Masters Students of Education?
2. Do you think that you were able to accurately reflect your attainment of these goals through your portfolio?
3. Which goals were most difficult for you to demonstrate in your portfolio?
4. Please comment on the value of the portfolio process.
5. What changes do you suggest to improve the portfolio process?

Content analysis was the method being used to analyze the portfolios and questionnaire data. For the questionnaire data, coding categories, previously established during a previous study, served as an initial framework for this study. The sentence served as the basic unit of text for coding and analyzing the data. Analysis of the questionnaire data followed an iterative process (Miles and Huberman, 1984). This included coding the data, creating data displays, seeking disconfirming and corroborative evidence; and identifying patterns, themes, and explanations. The patterns, themes, and explanations were organized and a descriptive narrative, along with supporting data, were written to describe the emerging understandings.

The analysis targeted questions related to the impact the process has on reflection and student understanding of program goals, and information about the attainment of program goals. Student responses to the questionnaire were coded with respect to the impact the portfolio process had on their understanding of program goals (Question 1 responses). Specifically, their responses were coded with respect to an emphasis on self-assessment, awareness of program goals, deeper understanding of the goals, or reflecting on teaching professional practices. Responses were coded with respect to these descriptions:

1. *Basic Knowledge/Awareness:* Responses in this category view the goals/standards as something to be covered, matched, checked off. The portfolio is viewed as an external measurement that someone else uses to judge performance. The student uses the goals/standards as a framework or organizational tool. The students' response indicates that there is a basic awareness or understanding of the goals/standards.

2. *Self-Assessment*: Responses in this category used the portfolio process to engage in self-assessment. The student may have used the goals/standards as a list or tool for self-assessment. The student indicates that the process has allowed for identification of personal strengths and weaknesses.

3. *Deeper Understanding:* Responses in this category demonstrate that the portfolio process has evoked a deeper or new understanding about the goals/standards. The portfolio has created a focus in implementing the goals/standards. The response focuses on, but has not moved beyond, a focus on the goals/standards to a focus on teaching.

4. *Reflective Thought on Teaching Practice:* Responses in this category have shifted to thought with respect to the art of teaching, rather than on the goals/standards. The response moves from

the specific information within a standard, to the big picture of teaching. Responses include information on effective teaching and "me as an effective teacher." The respondent has focused on personal practice rather than on the standards/goals.

Results

The results of this study have provided information about the processes of student reflection and growth in understanding that are cited as being important components of the portfolio process. The development of the coding process, through which student responses were categorized with respect to the impact the process has had on them, has gone through a great deal of refinement. In five cases, the students' responses included components of more than one category. Each component of the responses was coded according to the descriptions provided above (Figure 1).

For the undergraduate students who were involved in a portfolio process that has been developed and refined over many years, the results indicated that there was a nearly equal representation of three of the four categories. The category with the greatest number of responses was "Basic Knowledge/Awareness" with 27.3% of the responses. This indicated that although students had the opportunity to develop deeper understandings of the goals, teaching, and the portfolio process, they still viewed the goals/standards as simply a list or framework to use to prove one's competence. Student responses were coded equally into categories of "Reflection on Teaching" and "Deeper Understanding" with 25.3 % for each of these categories. Student responses were coded into the category of "Self-Assessment" less frequently with only 12.4 % of the responses in this category. Two students responded that the process had no effect on their understanding, twelve students did not respond, and five students had responses that were unrelated to the question.

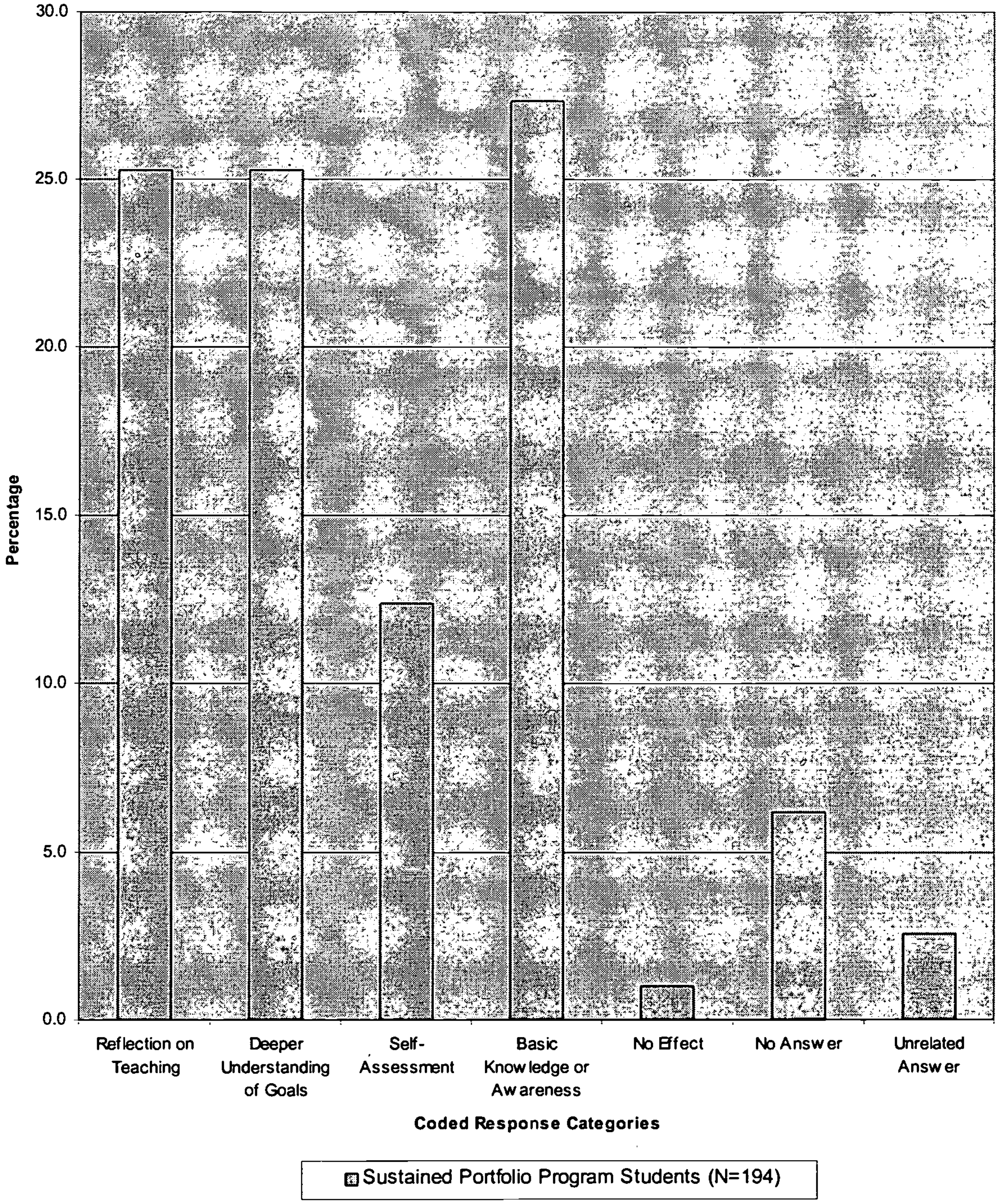

Figure 1. Effect of the Portfolio Process on Understanding of Program Goals

For the graduate students who were involved in a portfolio process that was recently

implemented, the results were different (Figure 2). This is a much smaller sample and the process changed each semester as information was collected. In this sample, the category with the greatest number of responses was "Reflection on Teaching" with 25.0% of the responses. Student responses coded as "Basic Knowledge/Awareness" included 20.8% of the sample and responses coded as "Deeper Understanding" represented 16.7% of the sample. There were no responses coded as "Self-Assessment" for this sample. Two students responded that the process had no effect on their understanding, two students did not respond, and five students had responses that were unrelated to the question. Many of the unrelated responses voiced the need for the portfolio process to be started at the beginning of the program and integrated throughout.

Conclusion

The results from this study indicated that the majority of students involved in the portfolio process made gains associated with the understanding of program standards/goals. Independent of the level of support provided by the program, students believed that the process had value. It was clear that the process had different effects for different students. The researchers believe that responses that were coded as "Reflection on Teaching," "Deeper Understanding of Goals," and "Self-Assessment" all involved reflective components. Students were reflecting on their teaching, what the standards mean with respect to their experiences, and their skills and knowledge, respectively. However, it was evident that students with responses coded as "Basic Knowledge" viewed the portfolio or goals as a tool and did not include aspects of reflection in their responses.

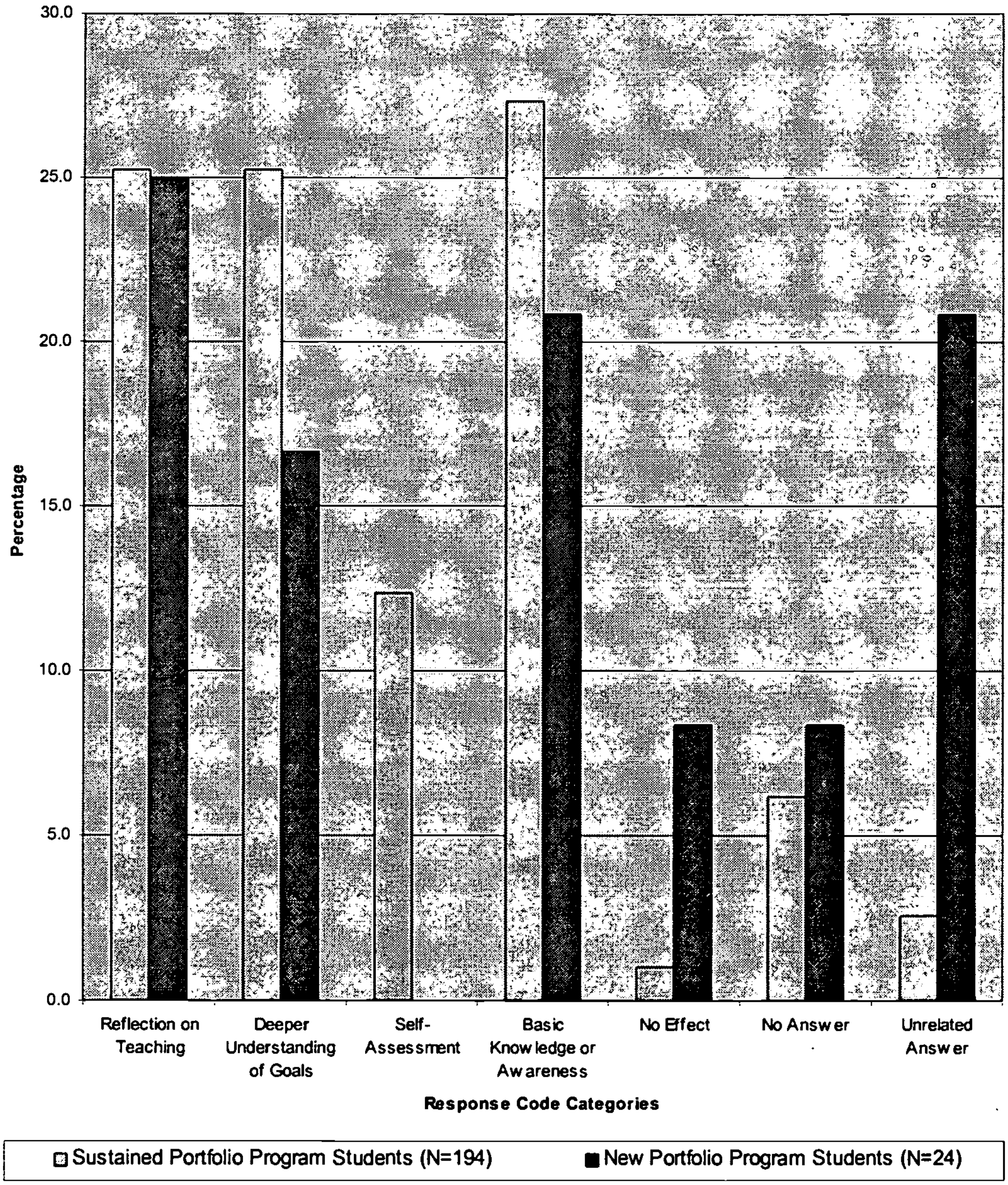

Figure 2. Comparison of the Effect of a New and Established Portfolio Program on Student Understanding of Program Goals

Because the samples were from two very different groups, it was not possible to attribute students' responses to a particular program characteristic. As the new portfolio programs develops and becomes institutionalized, we believe that we will see student responses change

over time. Specifically, we hope to see increases in the number of responses that indicate that portfolio process has been a reflective process for students.

Researchers have often promoted the portfolio process as one that evokes deep reflection. However, there are very few studies that show tangible evidence of the reflective process. We found that students often used the word "reflection" in their responses, but upon closer inspection, the nature of the reflection that took place varied. We are continuing to develop our coding process and refine the questions we ask students. We will continue to collect information and study the portfolio process as it develops within these institutions.

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THE SISTERS IN SCIENCE PROGRAM: A THREE YEAR ANALYSIS

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The Sisters In Science (SIS) program is an educational intervention aimed primarily at increasing the attitudes, perceptions, and achievement of fourth and fifth grade girls in science and mathematics. SIS is one of over 40 science education programs for Women and Girls, sponsored by the National Science Foundation (NSF). SIS is one of several government-funded programs established to address gender inequality in science and mathematics education.

Monies for programs like SIS came into existence via the passage of legislation. Such government actions included Title IX of the Education Amendments Act. Passed in 1972, Title IX was enacted to address the inequities in educational programs receiving federal dollars. In 1974, the Women's Educational Equity Act was passed. It expanded math, science, and technology programs for females. In 1994, a package of gender-equity provisions was included in the Elementary and Secondary Education Act. Among the provisions was the creation of teacher training activities that worked to eliminate inequitable practices and to develop programs to increase girls' participation in math and science (Parkay & Hardcastle-Stanford, 1998).

While legal barriers to achieving gender equity have been removed, there are often barriers we still face. These are barriers of the mind. Reform has been on the national agenda in science/mathematics education for more than a decade. The national reform movement has trickled down to state and local boards of education through the

development of state and local science/mathematics curriculum standards that not only advocate specific content but also equitable education. As schools search for the best models of instruction to help teachers become effective teachers, they are incorporating the standards into their curriculum. School administrators have little disagreement about the need for reform, but they have little agreement about the specific modes to achieve this reform (Linn, 1990). A commonly agreed-upon theme for reform is the active involvement of learners. Given a teacher's central role in the classroom, it is reasonable to hypothesize that the classroom culture is a function of a teacher's conceptions of not only science/mathematics but also equitable practice. Therefore, teachers are central to solutions and successes for current reform efforts. Unless we understand teachers' conceptions, why they hold them, and constraints in changing them, we will find it impossible to move from reformed curriculum to reformed practice. Therefore, teachers' conceptions must be examined as they reflect upon and apply the principles of reform. Furthermore, successful modes of achieving reformed practice must be examined.

Current science education reforms have focused on changing the curriculum, teaching and assessment in K-12 education to make it more equitable (National Research Council, 1996; Rutherford and Ahlgren, 1990). Specifically, the National Science Education Standards emphasize the "development of environments that enable students to learn science that provide equitable opportunities for all students to learn science" (National Research Council, 1996 pp. 4,7). However, recent studies on equitable practices in the classroom tell a different story of the current educational climate (Eder, Evans & Parker, 1995' Orenstein, 1994; Pipher, 1994). While much of the science education reform literature acknowledges the central importance of "equity issues", the

discussion centers around a "color-blind" points of view (Cochron-Smith, 1995; Ladson-Billings, 1995; Rodriques, 1997) rather than acknowledging differences in students. The Association for Educators of Teachers in Science indicate in their Professional Knowledge Standards that "unless prospective and practicing teachers can develop the knowledge, skills and beliefs called for in the reform documents little will change" (AETS, 1996). While the standards address the issue of equitable practice in the classroom they fail to capitalize on the importance of preparing teachers to address issues of equity in the classroom. Methods for equitable practice must be embedded into the reform initiatives to ensure that all students are given the best possible change for success.

Rationale

At the start of SIS the research literature was full of reasons and remedies for gender inequity in science and mathematics. One such line of research focused on the classroom environment. Studies suggested that within classrooms, males and females receive a very different education (Jones & Wheatley, 1990). Girls have less exposure to science equipment than do boys. Girls also become less active in science classes as they progress through the grade levels (Klein, 1991). Another avenue of inquiry suggested that teacher education programs featuring gender related instruction was lacking. Having examined the students' course project, Mader & King found that students advocated gender related instruction to a greater degree than they actually included it in their own teaching (Mader & King, 1995).

Perceptions about self and others were also mentioned as causes of disparities in the classroom. Shakeshaft (1995) says that science education classes have expectations that simply exclude girls leading to lower participation and achievement. Teachers' beliefs about students' abilities were said to affect the manner in which female students operate in the classroom (Shepardson & Pizzini, 1992). Such research identified teachers as the agents of gender bias. Jones and Wheately (1990) looked at a variety of teacher behaviors during science instruction. They concluded that the manner in which the teacher praised students, responded to call outs, warned students, and questioned students differed by gender. Likewise female students also tended to differ from their male cohorts in their receptivity to and participation in science education to the extent that female students contributed less often to classroom discussion than their male classmates do. A girl's perception of science also contributes to inequity in achievement. It has been found that female students harbor stereotypical ideas about science and scientists. They often feel that science is a male dominated field (Hammrich, 1996).

Reformists believe that there are some essentials to encouraging female student success by building gender-sensitive classrooms. They include fostering a safe and nurturing environment, promoting problem-solving skills, building math confidence creating collaborative experiences, using hands-on learning and allowing for open discussion about gender stereotypes, acknowledge the contributions and barriers of women in science , to utilize female-appropriate teaching and learning strategies, making math careers interesting and relevant (Allen, 1995; Mann, 1994, Boland 1995, Martin).

Constructivism, an epistemological perspective of knowledge acquisition, serves as the foundation for many of the noted suggestions regarding female-friendly science

education. By definition, of which there are many, constructivism is an approach to teaching. Constructivist believe that children learn by doing. Learning involves changing pre-existing schema using new information acquired through varied experiences (Damon et al., 1997).

Von Glasersfeld (1995) suggests that although Jean Piaget was not the first to speak about this way of knowing, he did spend years establishing the basis for a dynamic constructivist theory of knowing (p. 6). Piaget's notion of concept development suggested that humans come to know and understand their world through their personal experiences with and within it. Based in the theory of constructivism, Von Glasersfeld (1983) offers suggestions for teaching and learning. The first recommendation is that teachers should create an environment where individuals must interact both cognitively and physically with the environment in order to learn. Also, teachers must access students' prior knowledge to determine a suitable starting point for instruction. Wheately (1991) extends Von Glasersfeld's suggestions by stating that teachers should allow students to actively construct relationships and patterns, and work in cooperative learning groups. In addition, teachers should make material meaningful for students. Finally, science and mathematics institutions should be activity oriented and problem-centered in nature.

Science For All Americans a groundbreaking report written by the American Association for the Advancement of Science, set new standards for science, mathematics and technology education. This report on effective learning has offered several principles of learning that are founded in constructivist pedagogy.

What then should educators do to foster science learning in a constructivist fashion? Driver (1995) offers science education some suggestions. She posits that learners need to be given access to physical experiences as well as concepts and models of conventional science. Teachers need to be the presenters of experiences that enable students to make mental connections to pre-existing events. Driver's list by suggesting that students should have opportunities to: express themselves in oral and written form, work in teams, solve problems, question, explore and discover concepts, use authentic tools, and learn about related professions and professional contributions to the field.

Constructivist theory has also been expanded to include the training of science educators Neureither (1991) also believed that teachers should create scientist-like instructional experiences for students; understand and use the standards set by the American Association for the Advancement of Science; establish high standards for all learners. Teachers should model attitudes that foster inquiry and knowledge; and seek ways to connect science learning to other disciplines (Neureither, 1991).

Program Description

The Program

The rationale for SIS has its foundations in research on gender and achievement in science. Research suggests that female students have been found to lag behind their male counterparts in science achievement, this is due in part to science education practices that run counter to the intuitive learning style of female students. In addition, females tend to view the field of science as a male domain, often leading to the reluctance of girls to pursue science as a field of study or a career (Hammrich, 1996). In response,

SIS aims to serve female students with the intention of increasing girls' self-esteem, generating positive attitudes about science, interest in science careers, and sense of social responsibilities with regard to the environment.

The SIS intervention focused first on fourth-grade female students because research has found that female students, as young as nine years old, lag behind their male counterparts in science achievement for a variety of reasons (Hammrich, 1996). Research from the National Science Foundation (1990) and the Task force on Women, Minorities, and Handicapped in Science and Technology (1989) note that while efforts have been made to narrow this gap in achievement, little change has been realized (Hammrich, 1996).

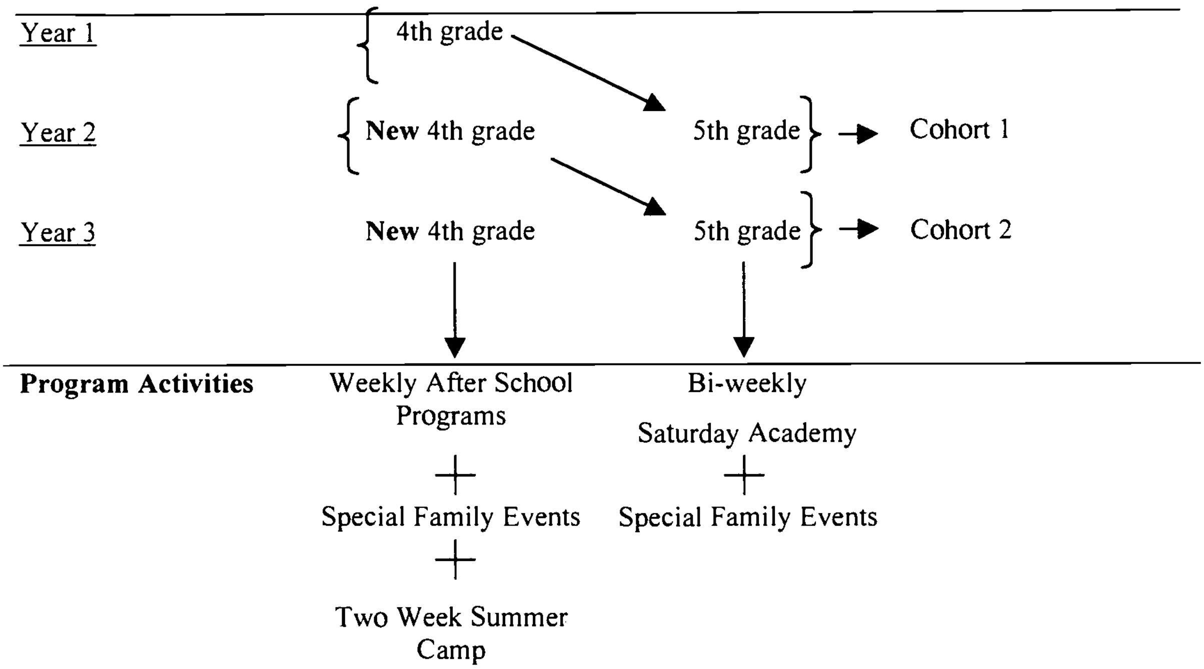
Sister In Science, a best practices model of effective integrated science and mathematics instruction, grew out of several years of research and testing. Two years prior to the funding of the existing "experimental" program there was a "model" program which was funded by NSF. The model program ran from 1995-1997 and served as the basis for the creation of the "experimental" program. The "model" program involved training preservice teachers to deliver effective science and mathematics instruction for inner city girls in an after school program and developing and piloting several science and mathematics activities.

Inherent in the existing program's focus is the recognition that female-specific intervention programs have a lasting impact on school success (Kaplan & Aronson, 1994). The program's efforts are also consistent with the call for systemic educational reform that recognizes gender-related, learning style-differences in science and mathematics (Tamir, 1988; Versey, 1990). Others involved in systematic educational

reform include the American Association for the Advancement of Science, the American Association of University Women, the Midwest Consortium for Mathematics and Science Education, the National Research Council, and the National Science Foundation.

The present "experimental" program, both a refined and expanded version of the "model" program, was designed under the guides of existing research findings on gender sensitive, constructivist, integrated science and mathematics instruction. SIS was funded to run from August 1, 1997 to August 1, 2000. The program was conducted in 6 elementary school each year. In year one, fourth-grade teachers, their female students, and the families of the girls participate in the program. In year two, rising fourth graders (i.e., fifth-graders) received additional program services while new fourth grade girls began the program. In the three years of program implementation two student cohorts encountered the full program intervention. In addition, fourth and fifth grade teachers received training and follow-up support in the delivery of the aforementioned "female-friendly" brand of instruction. (see figure 1 below)

Figure 1.



Two Year Intervention Model

The SIS program provided fourth- and fifth-grade girls with cooperative interdependent science exploration. The rationale being, when girls are allowed to work in a manner that is intrinsic to their collective learning style (e.g., with the manipulation of materials) learning will occur. Additionally, the program's designers were interested in the reformation of girls' perceptions of science education and science as a career option via reflective discussion as well as hands-on experience with science.

The goals of SIS include (a) increasing interest, achievement, self-esteem, environmental awareness, career awareness and attitudes in the area of mathematics and science (b) increasing inservice and preservice teachers' knowledge of the relationship between gender and effective instruction and (c) increasing parental knowledge of the importance of SEM in the lives of their children.

Program Components.

In order to attain these goals, the SIS program has four major components: (a) an in-school constructivist and gender-sensitive science program; (b) an after-school enrichment program for the fourth grade girls; (c) a Saturday academy for the fifth grade girls; and (d) a "city rivers exploration" summer camp.

The components of the program work in concert to provide 4th and 5th graders with a physical environment that is both psychologically, emotionally and socially safe and accessible to all students. The activities themselves engage students in instructional experiences that challenge everyone involved. The activities clearly connect subject matter to real-world issues that are culturally relevant to students. Whereas in the past, "a curriculum" has often meant a set of answers to be transferred from teacher to student, the curriculum as outlined in the SIS program is a set of questions to be posed to a class (Skilton Sylvester, 1997). In this way, the process of inquiry is co-constructed by the students and teachers and fosters a true community of learners. During each component of the program, students take responsibility for generating and gathering "data," posing questions and problems, generating possible explanations and proposing methods for evaluating the best explanations. Across all of the events, teacher, parents, volunteers, and Temple University students are providing a level of mentoring that extends the students learning base beyond the walls of the classroom.

The *in-school program* was conducted for two hours a week for each classroom at each of the six schools. Classroom activities focused on the urban environment and used gender sensitive approaches to teaching science/mathematics. As part of the program's teacher enhancement component, Students in science education methods courses at

Temple University facilitated the program sessions with the classroom teacher. The preservice teachers' coursework explored gender-equity issues in the classroom, the constructivist approach to learning, and the community service learning concepts presented in the program.

The *after-school program* was conducted from 3:00-4:30 p.m. one day per week in each of the six schools. The program coordinator facilitated the after-school component with assistance from graduate and undergraduate elementary education students and members of the intergenerational volunteer corps. The after-school component extended the classroom activities by focusing on the concepts of systems, constancy/change, model, and scale. The students also engaged in reflection activities designed to help them better understand their personal learning, challenge stereotypical notions about science, and develop critical thinking skills. These reflective activities included writing and interactive discussions.

The *summer program* was conducted for two weeks during July to reinforce learning that occurred during the academic year. Fourth grade females spent two weeks exploring the city rivers. Activities included taking four field trips to environmentally focused sites in the area, mapping local waterways, creating model rivers, and designing improvement plans to prevent the city rivers from becoming polluted. At the end of the summer program, the girls shared their learning with their families and other students from neighborhood elementary schools.

The *Saturday academy program* was conducted on Saturdays for four hours at a local site. Activities focused on expanding what the fifth grade girls learned during year one of the intervention. The fifth grade activities were designed to introduce a more

technology focus and a sport component. Sample activities that the girls participated in were taking apart and putting back together computers, developing web pages, and learning how to play tennis and fencing and learning the science and mathematical principles behind each sport. The fifth grade activities tied mathematics, science, and technology together.

Each of the central studies of the SIS program is structured around one or more central questions, which provides a focal point for the classes' inquiry. Each central study is woven by both unifying themes and cross-cutting competencies. The four unifying themes are: systems, models, scale, and constancy/change. The unifying themes constitute those skills that allow people to play effective roles in the community. For example, in the context of the classes' study of city rivers, students learn about *systems* as they study the water cycle. Along the way, the students discover the three states of matter: liquid, solid, and gas, a lesson which is fundamental to understanding *constancy and change*. Students learn about *models* as they create their own rivers. In creating their model of the river, students need to utilize the principal of *scale*.
The five cross-cutting competencies are: participatory citizenship, communication, multicultural competencies; problem-solving; and school-to-career readiness, technological literacy (School District of Philadelphia, 1996). In the study of city rivers mentioned above, students ask the question: "How do the city rivers get clean so that people can drink the water?" In searching for answers to this question, students engage in visiting a city water treatment plan, researching (with the help of the Internet) ways of making drinking water safe, and writing local scientists for their answers and suggestions. This lesson involves *problem solving, technological literacy, participatory citizenship,*

and *communication.* We might also ask, "How do different groups of people make the best of the city drinking water?" This might lead to learning about different ways of life of different ethnic groups, a lesson that "culture" is about values, beliefs and practices that guide our daily lives -- helping students develop *multi-cultural competencies.* SIS worked to meet its goals through a variety of activities.

Other components of the program that acted to reinforce the student program components included (a) teacher training program; (b) preservice training program; (c) family education program; and (d) volunteer corps.

The aim of the *teacher training* was for fourth-grade (Year one) and fifth-grade teachers (Year two) to increase their knowledge of the relationships between gender and effective instruction. These teachers, called cooperating teachers, are taught how to deliver gender-sensitive constructivist integrated mathematics/science instruction. Thirty-one teachers from six different schools located in Philadelphia's inner city participated in SIS over the past three years. Teachers participated in summer institutes each summer that focused on equitable best practice. At the end of each summer institute the teachers along with the science educators developed activities and guidelines to follow in the classroom the following year. Teacher participated in regular academic curriculum meetings throughout the year. The teachers' role during the academic year was multi-faceted. They taught equitable best practice science and mathematics lessons along with supervising education elementary practicum students three hours a week as part of the in school part of the program.

The goal of the *preservice teacher training* was to increase their knowledge of the relationships between gender and effective instruction while engaged in the

experiences of their practicum. Through the practicum and methods coursework and interactions with their cooperating teachers Temple students are made aware of the connections between gender and effective instructional practices. They are also taught how to deliver integrated mathematics/science instruction. The preservice teachers worked in teams to instruct 4^{th} and 5^{th} grade students under the supervision of cooperating teachers one day each week.

The *family education*. Program participants and their families attend quarterly events throughout the year. These events reinforced and showcased students learning throughout the academic year. Events included a science night, a trip to the New Jersey State Aquarium, an overnight at the Franklin Institute, and an end of the year awards banquet.

The *volunteer corps* included retired and working science and science-related field professionals working with program participants. These retired and active science professionals interact with the girls in order to develop the students' connections with science and science-related careers and professions.

Program Evaluation

Method

For the purposes of this research the program will be evaluated in a Gestalt like fashion as the sum of its parts. The parts or components include (a) the student component (b) the teacher component (c) the preservice teacher component and the (d) family education component. However, the following questions transverse the aforementioned components of the program.

Process Evaluation

1. Who are the participants in the program?

2. What are the activities of the individuals who participate in the program?

3. What is the nature and source of the instruction/information imparted to the participants?

Outcome Evaluation

1. Did girls increase their attitudes, interests, and achievement in mathematics and science?

2. What are fourth grade teachers' conceptions of science/mathematics teaching?

3. Were teachers' conceptions of science/mathematics teaching influenced as they confront the gender gap?

4. Did parents and guardians gain knowledge of mathematics and science?

Instrumentation

Multiple data collection procedures were employed to assemble information that addressed the research questions. Information collected on students consists of demographics, attitude, perceptions, and achievement. At the start of each school year students completed the Fourth Grade Student Demographic Survey. Pre-post test instrumentation was used to measure achievement as well as attitudes. Achievement was measured by an integrated mathematics/science, open ended, hands-on skills test designed around the science process skills. SIS staff constructed the skills and demographic instruments. The skills test content reflected materials contained in the fourth and fifth grade curriculum of the School District of Philadelphia. Attitudes were measured by the Science Attitude Scale, a 30 item instrument with a 5-point likert

response scale (strongly disagree to strongly agree) (Meyer & Koehler, 1988). Finally, student perceptions were measured by the Draw A Scientist (DAST) instrument (Mason, Kahle, & Gardner, 1989)

Data collection activities for the teacher component began with a demographic instrument, subsequent focus groups and a pedagogy checklist. The Cooperating Teacher Demographic survey was constructed by the SIS staff. The semi-structured and open-ended focus group questions were designed to elucidate teachers' conceptions of science/mathematics and their perceptions of confronting the gender gap. Teachers completed two 2-hour focus group sessions each academic year. The first focus group was conducted half way through the school year and the second focus group was conducted at the end of the school year. During the focus groups teachers were asked to reflect upon their conceptions about science and mathematics. They were also asked to reflect on any changes that occurred in their practice and the consequent impact their instruction had on their students. Teacher's instructional activities were measured using a Classroom Teacher Observation Checklist. The 25-item checklist, administered in the spring of each year, sought information on teacher-student interactions, conceptual change-pedagogy, atmosphere and activity type. The items were based on gender-sensitive research. The observations were done at the teacher's convenience therefore they may not have represented a typical performance.

The preservice teacher component data collection activities were numerous. A demographic survey was conducted along with a Pretest/Posttest Practicum Student Surveys. Again, the demographic survey was constructed by SIS staff. Preservice students were surveyed at the start each semester regarding prior knowledge of

constructivism and gender equity. They were asked to indicate (a) "none" (b) "some" or (c) "extensive" for two questions: "What knowledge do you have of gender equity issues in the classroom?" and "What knowledge do you have of constructivist learning?" At the end of each semester the preservice students were surveyed on a variety of issue. Questions of concern to this investigation asked whether or not preservice teachers were exposed to issues of gender equity, integrated instruction, or constructivist pedagogy in the classroom and from where they received their information.

Data collection activities for the family education component consisted of event logs, and satisfaction surveys. At the end of each event program participants and their families were asked what they liked and what they would change about the event. In addition they were asked rate their experience on a three point scale of poor, fair, or good.

Data Analysis

With respect to the student component the analysis was primarily quantitative. Pretest-posttest comparisons were done at each grade level for the Science Attitude Scale, the DAST, and the achievement (ie., skills) test. The *t*-test for independent samples as performed for the attitude scale and the achievement test, while percentages were used to determine differences in perceptions on the DAST. The student data was analyzed in two cohort years (1997-1999 and 1998–2000).

The inservice teacher component focus group data was analyzed using grounded theory (Strauss, 1987). Focus group responses were videotaped, transcribed and coded in a data file using Ethnograph v.4.0. Cases were examined as a whole. Extensive memoing and preliminary assertions were logged as focus group responses were

conducted, transcribed, read, and re-read to find words, phrases and themes that reflected teachers conceptions concerning science/mathematics teaching and perceptions of confronting the gender gap. The focus group responses were analyzed using Patton's (1990) method for generating themes. Through the constant comparative method (Strauss, 1987) themes emerged and assertions developed. From these preliminary assertions were made and data was highlighted as to possible warrants to support these assertions. Coding of data included both inter-rater and intra-rater reliability as well as several other provisions for trustworthiness.

Finally each teacher was observed implementing an equitable best practice science and mathematics lesson during the spring of each school year. Each observer filled out a predetermined observation checklist to note the occurrence of gender-sensitive, constructivist, and integrated science and mathematics instruction. Frequency counts and percentages were done on each item of the checklist. Counts and percentages were also calculated for each subscale.

Family education and preservice teacher data analysis was primarily quantitative. Frequency counts were used to determine patterns and other commonalties in data for both open-ended and closed-ended questions.

Results. There were a total of 2,037 students participating in the program with an average of 54% (1,100) girls for the total three years. Both the boys and girls participated in the in school portion of the program. In year one there were a total of 166 fourth grade girls from the six schools who participated in the after-school program and 36 fourth grade girls who participated in the summer program. In year two there were a total of 95 fourth grade girls who participated in the after school program, 44 fifth grade girls who

participated in the Saturday academy, and 42 fourth grade girls who participated in the summer program. In year three there was a total of 96 fourth grade girls who participated in after school program, 36 fifth grade girls who participated in the Saturday academy, and 38 fourth grade girls who participated in the summer program. (see tables 1 and 2)

Table 1.

Gender and Ethnicity of Students by Percent

Item	Response Category	Percentages 1997-1998 N=577	1998-1999 N=790	1999-2000 N=670
Gender	Males	43	48	46
	Females	57	52	54
Ethnicity	African American	64	67	63
	Caucasian	2	2	1
	Puerto Rican	19	19	17
	Indian	1	2	1
	Asian	9	9	8
	Mixed/Other	5	2	9

Table 2.

Demographic of Girls by Program Component

Component	1997-1998	1998-1999	1999-2000
After school	$N = 166$	$N = 95$	$N = 96$
Saturday Academy		$N = 44$	$N = 36$
Summer Program	$N = 36$	$N = 42$	$N = 38$

The student data was divided into two 2 year cohorts 1997-1999 and 1998-2000.

For cohort one (1997-1999) there were 299 fourth grade girls who completed the attitude pre assessment and 259 fourth grade girls who completed the attitude post assessment. For year two, the fourth grade girls now fifth grade girls there were 215 completed attitude pre assessments and 208 completed attitude post assessments. Table 3 shows that there was a significance found between the fourth grade girls scores pre to post . There was also a significance found between the fourth grade girls pre and their post fifth grade scores. For cohort two (1998-2000) there were 207 fourth grade girls who completed the attitude pre assessment and 211 fourth grade girls who completed the attitude post assessment. For year two, the fourth grade girls now fifth grade girls there were 103 completed attitude pre assessments and 87 completed attitude post assessments. Table 3 shows that there was a significance found between the fourth grade girls scores pre to post. There was also a significance found between the fourth grade girls pre and their post fifth grade scores. The responses were scored 1 = strongly disagree, 2 = disagreed, 3 = neutral, 4 = agree, 5 = strongly agree. Scores above 3.0 indicate the students agreed or strongly agreed with the statements on the subscale.

Table 3.

Science Attitudes Scale Mean Scores

	Pre	Post
Cohort 1		
4^{th} (yr 1)	3.88(n=299)	3.96*(n=259)
5^{th} (yr 2)	4.03 (n=215)	3.99* (n=208)
Cohort 2		
4^{th} (yr 2)	3.71(n=207)	3.88* (n=211)
5^{th} (yr 3)	3.91 (n=103)	3.90* (n=87)

* significant difference $p < .05$

The students perceptions for *cohort one and cohort two* were measured by the *Draw a Scientist* test (Mason, Kahle, & Gardner, 1989). The occurrence of characteristics for each drawing were counted (see Table 4). On both the pre and post tests for both cohort years a majority of the girls drew female scientists. There was no significant change. What is interesting to note is that the cohort one girls in their 5^{th} grade year drew more gender neutral scientists then either scientists as girls or boys.

Table 4.

Percentages of Responses for Draw A Scientists Test

	Draws Male (DM) Draws Female (DF)	Pre	Post
Cohort 1		(n=266)	(n=239)
4^{th} (yr 1)	DM	19%	20%
	DF	71%	71%
		(n=214)	(n=179)
5^{th} (yr 2)	DM	9%	13%
	DF	27%	31%
Cohort 2		(n=186)	(n=199)
4^{th} (yr 2)	DM	27%	12%
	DF	30%	57%
		(n=177)	(n=125)
5^{th} (yr 3)	DM	18%	23%
	DF	66%	72%

* significant difference $p < .05$

For cohort one (1997-1999) there were 276 fourth grade girls who completed the skills pre assessment and 226 fourth grade girls who completed the skills post

assessment. For cohort year two, the fourth grade girls now fifth grade girls there were 247 completed skills pre assessments and 233 completed skills post assessments. Table 5 shows that there was significance found between the fourth grade girls scores pre to post on the total test score, skills 1, 3/4, 5, 7/8, and 9-12. There was no significant difference found between the fourth grade girls pre and their fifth grade post scores. However, significance was found between the fifth grade girls scores pre to post for the total test, skill 2, and 3/4. For cohort two (1998-2000) there were 333 fourth grade girls who completed the skills pre assessment and 344 fourth grade girls who completed the skills post assessment. For cohort year two, the fourth grade girls now fifth grade girls there were 148 completed skills pre assessments and 130 completed skills post assessments. Table 5 shows that there was a significance found between the fourth grade girls scores pre to post on the total test score, skills 2, 3/4, and 6. There was also a significance found between the fourth grade girls pre and their post fifth grade scores on the total test core and skills 1, 5, 6, and 9-12. When looking at the fifth grade girls scores there were significant difference found pre to post on the total test score and skill 6.

Table 5.

Means for Skills Test

		Cohort 1				Cohort 2			
		4th (yr 1)		5th (yr 2)		4th (yr 2)		5th (yr 3)	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Skill	Max. Points	*n*=276	*n*=226	*n*=247	*n*=233	*n*=333	*n*=344	*n*=148	*n*=130
1	5	4.46	4.60*	4.57*	3.51	4.53	3.45	4.52	4.66**
2	4	3.66	3.69	3.47	3.71*	3.45	3.76*	3.50	3.46
3/4	4	3.00	3.28*	3.12	3.34*	3.12	3.45*	3.25	3.25
5	4	1.58	2.26*	1.14	1.05	1.88	2.16	2.22	2.33**
6	3	.97	.96	.80	.80	.81	.82*	.78	.92**
7/8	6	3.43	3.72*	3.68*	3.43	3.74*	3.49	2.32	3.78
9-12	12	2.95	4.46*	2.85	3.82	3.00	4.00	3.71	5.09**
Total	38	20.21	24.40*	20.40	20.80*	20.53	21.14*	22.06	23.50*

Note: Skill 1 – observation, Skill 2 – symmetry, Skill 3 & 4 – Classification, Skill 5 – measuring, Skill 6 – averaging, Skill 7 & 8 – predictions, Skill 9-12 – experimental procedures.

* significant difference pre to post ($p<.05$)

**significant difference pre to post ($p<.05$) between cohort pre and post

Results were also obtained on the Stanford Nine national test. All fourth grade classrooms take this national test each year (note. 1999-2000 year data was not yet available for this presentation) . There was a gain on the scores for each school for each year of the intervention. No statistical test was run to see if their was a significant difference on the gain scores (see Table 6).

Table 6.

Stanford Nine Point Scores for Fourth Grade

	Baseline	Year 1	Year 2
Schools	1996-1997	1997-1998	1998-1999
Childs	71.3	72.5	65.7
Clymer	43.9	51.6	79.7
Dunbar	56.5	63.5	66.1
Ferguson	55	63	63.7
Morrison	70.5	79.2	81.9
Olney	62.6	77.5	78.9

There were 31 total teachers who participated in the program over the three years of the intervention. In year one there were 17 fourth grade teachers in years two and three there were 25 fourth and fifth grade teachers each year. These numbers represent teachers who were involved in the program for the entire three years and other teachers

who participated one or two years. Of all the teachers who participated in the program they had varied demographic exposure to program components prior to the program.

Table 7.

Cooperating Teacher Demographic Survey

Item	Response Category	1997-1998	1998-1999	1999-2000
		n=17	*n*=25	*n*=25
Gender	Male	6%	4%	4%
	Female	94%	94%	96%
Ethnicity	African American	41%	20 %	24%
	American Indian/Alaskan	0	0	0
	Hispanic	0	0	4%
	Asian American	6%	4%	4%
	White	53%	76%	68%
	Other	0	0	0
Certification K-12	K-8	88%	76%	76%
	1-6	6%	12%	0
	K-6	6%	12%	24%
Highest Degree Earned	Bachelors	12%	16%	44%
	Masters	53%	44%	28%
	Masters +30	35%	40%	28%
	Doctorate	0	0	0
Certified to Teach	Elementary Math	35%	6%	4%
	Elementary Science	29%	52%	4%
	Middle School Math	0	16%	8%
	Middle School Science	0	8%	8%
	Elem Math and Science*	24%	0	48%
Years of Teaching	0-5	35%	28%	48%
	5-9	6%	36%	16%
	9-15	6%	20%	20%
	16-25	35%	16%	12%
	25+	18%	0	4%
Science Classes in College	Astronomy	0	12	8%
	Chemistry	18%	40%	48%
	Physical Science	30%	28%	40%
	Physics	18%	24%	28%
	Geology	30%	16%	24%
	Biology	47%	52%	28%
	Oceanography	6%	0	4%
	Other	6%	12%	12%
Non-Science Major Credit Hours	9-12	47%	16%	68%
	15-18	0	72%	4%
	18-21	24%	4%	4%
	21-25	0	4%	0
	25+	0	4%	4%
	8 or less*	12%	0	0

Results gathered from the teacher observation were used to judge the effectiveness of the intervention. Results showed that there has been a real change on the part of the teachers over the three years of the program. Specifically, teachers reported that as a result of the cooperation between the schools and the university, they were continurally teaching science and mathematics more often and more effectively; promoting connections with other subject areas, adopting more gender equitable constructivist approaches to teaching science and mathematics, and changing their own attitudes about science and mathematics in a positive direction (see Table 8).

Table 8.
Classroom Teacher Observation Checklist

Item	Yr 1 *n*=16	Yr 2 *n*=27	Yr 3 *n*=5*
Interactions			
Teacher equally engages boys and girls in dialogue.	100%	59%	100%
Teacher interacts equally with boys and girls.	100%	52%	100%
Teacher equally encourages boys and girls to accept the same roles in the classroom	94%	41%	80%
Teacher listens to boys and girls equally.	100%	52%	80%
Teacher equally acknowledges boys and girls' responses/explanations.	100%	37%	60%
Students work in a cooperative manner.	75%	37%	80%
Boys and girls do similar tasks in the classroom.	100%	96%	100%
Average	96%	53%	86%
Conceptual Change-Pedagogy			
Teacher equally engages boys and girls in higher order thinking.	94%	15%	80%
Teacher assesses prior knowledge.	94%	15%	80%
Teacher confronts misconceptions.	88%	30%	80%
Teacher corrects misconceptions.	88%	11%	40%
Teacher accepts more than one right answer.	94%	19%	80%
Teacher equally asks open-ended questions of boys and girls.	94%	11%	60%
Teacher equally encourages boys and girls to initiate questioning.	31%	0	40%
Average	83%	16%	66%
Atmosphere			
Diverse images of scientist/science careers are present (gender, race/ethnicity, age).	13%	34%	60%
Teacher makes references to science and careers in science.	31%	15%	60%
Teacher connects classroom activities to real life experiences for students.	81%	74%	80%
Average	42%	41%	67%
Activity Type			
Activities are hands-on.	75%	74%	100%
All students use authentic tools and manipulatives to solve problems.	75%	70%	100%
Activities are cooperative in nature.	75%	70%	100%
Activities integrate math and science skills.	56%	52%	100%
Teacher accepts a variety of student performance outcomes.	36%	70%	80%
Teacher allows for student exploration.	81%	81%	60%
Teacher allows for student lead instruction.	25%	22%	80%
Activities are structured.	94%	96%	100%
Average	36%	67%	90%

In response to the focus group reflective dialogue sessions there was seen real change on the part of the teachers conceptions of science and mathematics teaching and in confronting equity issues during the course of instruction. Teachers' conceptions change from indifference to acknowledgement to embracement of teaching for all throughout the three years of program implementation.

Table 9.
Select Comments from Focus Group Sessions

Questions	Fall 1997	Fall 1998	Fall 1999
Were you able to teach more science?	No additional science taught Two teachers had additional science prep periods	11 teachers stated they taught additional science	Teachers are becoming better mentors and also more aware of what constitutes a good lesson
Has your teaching change? How?	More of an awareness Self reflection Have acquired new strategies More hands on Girls are more involved	More hands on More coordination with science teachers Began to model Temple students methods of delivery and lesson plans Students engaged in more scientific process and more research	Teachers say they don't tell as much. They are learning to let the students make mistakes Many of the teachers said that they are integrating science into their other subjects like reading and language arts
Has your teaching become more gender sensitive? How?	Tried to utilize different learning styles beyond gender issues	Yes it is more gender sensitive Become more conscious of calling on students More equitable Students became more interested	Many of the teachers who were in the program for three years stated that they feel their teaching style encompasses the issue of gender equity New teachers to the program are becoming more aware
Are you more comfortable with science teaching?	yes	yes	Yes, but I am always learning

There were over 600 preservice teachers who participated in the program over the course of the three years of implementation. In order to account for their conception changes as a result of their participation several instruments were administered. In this paper we selected a random sample of students for three semesters of the six semesters of program implementation. A survey at the beginning of their involvement in the program revealed a mixture of demographics and a lack of knowledge of the pedagogical principles employed in the program. (see table 10).

Table 10.
Preservice Teacher Survey and Demographics

Items		Fall 1997	Fall 1998	Fall 1999
		n=92	n=82	n=79
Year	Freshman	0	0	1%
	Sophomore	0	0	0
	Junior	12%	4%	9%
	Senior	87%	95%	91%
	no response	1%	1%	0
Status	Full-time	95%	96%	2.5%
	Part-time	0	2%	86.1%
	No response	5%	2%	11.4%
Methods Course Completion	Math Ed 141	19%	18%	5.1%
	Science Ed 151	33%	6%	11.4%
	Other	32%	0	41.8%
	Math/Science	9%	0	7.6%
	Two or more	17%	0	31.6%
Teaching Experience	Practicum +/-	98%	83%	70.1%
	None	1%	17%	3.8%
	Other	1%	0	49.4%
	No response	0	0	0
Knowledge of Gender Equity	None	13%	4%	3.8%
	Some	74%	83%	79.7%
	Extensive	13%	13%	16.5%
	No response	0	0	0
Knowledge of Constructivism	None	32%	13%	13.9%
	Some	57%	7%	77.2%
	Extensive	10%	77%	8.9%
	No response	2%	3%	0
Knowledge of Developmental Issues	None	21%	7%	17.7%
	Some	73%	76%	70.9%
	Extensive	5%	13%	10.1%
	No response	1%	4%	1.3%

At the end of each semester the preservice teacher completed post survey to find out the nature of their instruction during the semester of their involvement in the program and where they obtained the information. (see table 11, 12, 13).

Table 11.
Preservice Teacher Post Survey Fall 1997 n=101

TOPICS	Math 141	Science 150	practicum supervisor	cooperating teacher	other
gender sensitive instruction	36%	55%	35%	17%	26%
assessment techniques	65%	56%	40%	19%	36%
cooperative learning	67%	65%	54%	37%	37%
hands-on/minds-on activities	68%	76%	56%	37%	31%
demonstration activities	62%	67%	47%	24%	18%
lesson plan development	58%	68%	53%	18%	34%
unit development	58%	60%	54%	19%	18%
classroom management techniques	37%	31%	54%	45%	39%
leading group discussions	33%	36%	34%	24%	30%
questioning techniques	51%	51%	44%	30%	34%
benchmarks/standards	45%	84%	31%	13%	17%
adaptive instructional strategies	54%	49%	35%	24%	26%
authentic activity development	58%	61%	36%	21%	29%

Table 12.
Preservice Teacher Post Survey Fall 1998 *n*=93

TOPICS	Math 141	Science 150	practicum supervisor	cooperating teacher	other
gender sensitive instruction	51%	45%	56%	24%	18%
assessment techniques	73%	49%	36%	35%	22%
cooperative learning	74%	56%	45%	49%	26%
hands-on/minds-on activities	76%	72%	36%	35%	18%
demonstration activities	74%	67%	28%	32%	16%
lesson plan development	70%	56%	49%	30%	21%
unit development	66%	44%	39%	23%	24%
classroom management techniques	64%	38%	51%	45%	22%
leading group discussions	45%	39%	33%	24%	18%
questioning techniques	58%	58%	32%	28%	19%
benchmarks/standards	74%	64%	37%	19%	10%
adaptive instructional strategies	57%	47%	31%	24%	21%
authentic activity development	69%	55%	32%	24%	18%

Table 13.
Preservice Teacher Post Survey Fall 1999 *n*=41

TOPICS	Math 141	Science 150	practicum supervisor	cooperating teacher	other
gender sensitive instruction	22%	18%	21%	15%	4%
assessment techniques	34%	20%	15%	14%	6%
cooperative learning	36%	25%	19%	21%	6%
hands-on/minds-on activities	37%	32%	17%	25%	5%
demonstration activities	31%	26%	15%	17%	5%
lesson plan development	32%	24%	22%	18%	4%
unit development	32%	20%	9%	13%	4%
classroom management techniques	25%	12%	23%	28%	3%
leading group discussions	16%	13%	11%	13%	4%
questioning techniques	21%	19%	20%	21%	7%
benchmarks/standards	36%	31%	19%	10%	5%
adaptive instructional strategies	26%	22%	15%	15%	3%
authentic activity development	27%	21%	15%	20%	2%

Each year of program implementation there were four quarterly family events. Events included a science night, a trip to the New Jersey State Aquarium, an overnight at

the Franklin Institute, and an awards banquet. At each event the families were surveyed to determine their level of satisfaction with each event. (see table 14)

Table 14.
Family Education Activities. Attendance and Satisfaction Survey Results

Activity	1997-1998		
	Attendance	Average Rating	Average Percentage
Science Night	*n*=70	1	87%
NJ State Aquarium	*n*=90	2	12%
Franklin Institute	*n*=80	3	1%
Awards Banquet	*n*=84		
Activity	1998-1999		
	Attendance	Average Rating	Average Frequency
Science Night	*n*=218	1	86%
NJ State Aquarium	*n*=65	2	12%
Franklin Institute	*n*=100	3	2%
Awards Banquet	*n*=75		
Activity	1999-2000		
	Attendance	Rating	Frequency
Science Night	*n*=270	1	92%
NJ State Aquarium	*n*=100	2	7%
Franklin Institute	*n*=84	3	1%
Awards Banquet	*n*=137		

Discussion

Summary of Findings

Results of the Science Attitude Scale showed that the girls attitudes toward science and the possibility of pursuing a career involving some aspect of science and/or mathematics were positive before program implementation. Anecdotal information regarding the girls revealed that while they enjoyed science and perhaps someday wanted to become a doctor or have a career in science, they were not aware that it was necessary to take science classes in the future. Therefore their attitudes did not match their

understanding of how science courses fit into their eventual career path. However, their expressed positive attitude towards science is consistent with the research that states girls at this age level tend to enjoy science (AAUW, 1992). In the 5th grade of each cohort year the fifth grade girls attitude continued to be positive and significantly higher than the fourth grade girls attitude. This maybe due to the fact that these fifth grade girls participated in fourth grade and chose to participate again in year two in the fifth grade.

Regarding girls perceptions of science, the girls tended to draw female scientists both pre and post. What was noticed in year two of cohort one was that a majority of the girls tended to draw gender neutral scientists. This is an observation that needs to be further explored.

Results from the science/mathematics process skills instrument in cohort one indicated a mixture of statistically significant changes for the girls participating in the program. This was a combination of small losses and small gains for the six schools involved. We entered each school with a commitment to service all 4th grade classrooms. Therefore no control groups existed within the schools. In other words no "control vs. experimental' group analysis was warranted. Clearly, to the extent that the instrument was appropriate to the problem, a majority of the outcomes did meet the expectation of an increase in the science process skills. Of the skills tested, all of them appeared in the fourth and fifth grade Philadelphia curriculum.

Achievement was also measured using the grade four Stanford Nine science scores. All six schools 4th grades tested at each school saw an increase in their scores over the years of SIS intervention. No statistical test was run on the data. Stanford Nine scores are published by the School District for public consumption each year. In year one there

was a range of growth scores for the six schools from 1.2 to 14.9 with the average gain score 7.9 overall. In year two the range of increase for the schools was from 1.2 to 35.6 with the average gain score of 8.8. The rate of change was 50% higher for SIS than non-SIS 4th grade schools in the district. While it is not possible to single out the SIS intervention as the only contributing factor to the increase in scores, Principals at all schools were very generous in their praise for SIS intervention being a contributing factor for their schools' score increases.

By the time teachers enter the teaching field they have already developed a conception of teaching and learning (Perry, 1990). Quite often they have not reflected on their conception of science and delivery of equitable instruction and how their conceptions influences their conception of effective equitable science instruction. Preliminary training led us to believe that "equity" was not a much thought about topic with respect to science by all of our participants. As this study shows while teachers are accepting of examining and even embracing new conceptions of science teaching, many of the teachers still cling to their prior conception of science teaching when pressed with uncertainty in a teaching situation. This may be due to lack of practical experience, reflection, or lack of specific knowledge in the area of gender equitable science and mathematics instruction. However, exposure over a period of time helps to illiviate many uncertainties. This conclusion can support efforts to have sustained professional development on specific pedagogical issues rather than stand alone sessions on many pedagogical issues.

Research suggests that teachers' beliefs and reflections are important drivers of classroom actions and thus need to be considered in understanding changes in practice or

any lack thereof (Peterson, Fennema, Carpenter & Loef, 1989; Schon, 1991). Beliefs act as the theories that guide actions and reflections and dialogue allow an examination of those actions in terms of one's beliefs and promote necessary modifications in either actions or beliefs.

Reflection and dialoguing on their practice in the classroom, teachers expressed that they are more aware of what they need to do in the classroom to promote equitable practice that is constructivist. All of the teachers expressed that they were not always conscious of practices that exclude girls in the learning process but as they reflected upon their teaching they became more conscious of their practice and were able to adjust their teaching to include all students, not just the girls, in the learning process. The teachers said that being part of the programs design and having open dialogue with one another and the SIS staff helped them in their reflection and practice. They felt less isolated and more involved in the reform process in their classroom.

Many of the teachers said they enjoyed teaching science more. A number of teachers expressed that they have developed new ways of teaching science and mathematics throughout the year. All of the teachers expressed the belief that involving all students in the learning process was crucial for effective teaching. The teachers noticed that their students became more excited about learning when they were actively engaged in activities. They also noted that the girls seemed to blossom in the classroom when they were working on projects or in groups.

Teachers agreed that they have become more reflective of their teaching experience. However, the teachers did express the concern that when they are confronted with teaching a science topic that is new and unfamiliar they tended to revert back to a

more traditional teaching approach. They also noticed that when this occurred the girls became less participatory in the activities. Specifically related to equitable practice, teachers revealed that not all their lessons make a connection to gender sensitivity but they are still learning and trying new approaches. This was a concern expressed by all the teachers. However, they said that by just being conscious of this occurrence was helping them change their teaching practice. They tend to be mindful of what is occurring and try to change their practice.

Implications

The SIS program seeks to increase elementary girls' interest and achievement in science and mathematics, create a more positive learning climate for minority school girls and their families on academic and community/social levels, and increase the knowledge base and understanding of parents with respect to their influence in promoting girls' interest and achievement in science and mathematics. Findings to date show that the girls started the program with positive attitudes and perceptions of science and about science career possibilities. The girls did significantly increase their science and mathematics skill levels after having participated in the program. It could be stated that the girl's achievement scores on the skill test increased significantly because the girl's attitudes and perceptions were high before program implementation. If their attitudes and perceptions were low to begin with perhaps their skills would not have increased significantly.

Also, the call for systemic reform presents a great challenge in facilitating teachers' conceptions of science/mathematics teaching and practices of confronting the gender gap. In order for teachers to model practices of teaching that promotes gender equity in science and mathematics, they must participate in reflective practice. Teachers

must be actively involved in the process of reform because they are the change agents of reform in the classrooms. Reforming science/mathematics teaching that confronts the gender gap requires reforming teachers conceptions first. Unless teachers reflect upon and practice reformed teaching strategies that promote gender equity, it is unrealistic to expect change.

As schools strive to embed equitable practice into their curriculum they must actively involve teachers in the process of reform. The implementation of new teaching approaches that involve equity has to have a reciprocal relationship with teachers conceptions and actions, because teachers are the agents of reform in the classrooms. How reform in the practice of promoting equity in science education should be implemented in a classroom must be informed by teachers' conceptions of science teaching and equitable practice. Likewise, teachers need to be informed by the research on equitable practice.

Limitations

There are several limitations that may have hindered the outcome of program results. First of all there was no control group comparison; therefore, other factors unknown to the researchers could have mediated the results. In the future, there will be made allowances to include a control group. A second limitation could be a "Hawthorne" like effect. Prior to program implementation there were no hands on, integrated science and mathematics experiences taking place in the six schools. Another limitation was that matched sampling was not employed pre to post. This might have yielded more dramatic differences in progress from fall to spring. Lastly, school

populations are often transient. Therefore, the fall sample may not have matched the spring sampling. In the future random sampling across all instruments may be warranted.

In the successive years of the program, the researchers will attempt to look at longitudinal affects on the girls' attitudes, perceptions, and achievement levels. Since the girls held positive attitudes towards science before program implementation it may warrant a closer look at the cultural and familial factors that my have contributed to the girls attitudes. While the program has been promising, many more questions still remain and new ones have developed. In an attempt to answer these questions, the researchers will look for ways to improve program implementation. What became evident in the program implementation was that (a) parental behavioral expectations for their daughters have important implications for females' interest and achievement in science and mathematics; (b) intervention programs that are specifically designed to include role models have a strong and positive impact on females' achievement in science and mathematics and assist females to identify with science and mathematics as possible areas for study or employment; (c) program interventions evolve in stages of development, growth, and change. In order to promote the sustained success of females in science and mathematics, there must be a conscious effort to provide support for collaboration among schools, parents, and the community as ideas for useful strategies are developed, implemented, and evaluated.

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TEAM: STAFF DEVELOPMENT AND MENTORING FOR URBAN ELEMENTARY TEACHERS, PRESERVICE TEACHERS, AND STUDENTS

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The need for continual staff development among teachers is implied by the proliferation of standards documents (AAAS, 1993; NRC, 1996) addressing science education. In particular, the National Research Council's (1996) *National Science Education Standards* moves beyond the implicit to state that teachers should "participate fully in planning and implementing professional growth and development" (p. 52). The policy of improving teacher skills in science education is a task that has been embraced by universities, states, non-profit organizations, school districts, individual schools and individual teachers (Joyce and Showers, 1988). Urban schools, with resources taxed more so than suburban schools, face greater challenges in terms of student achievement and staff development (Hodges, 1996). To examine the value of staff development experiences is critical in this environment of limited resources. To this end, the authors examined the value of staff development programming through the constructs of science teaching self-efficacy and science teaching outcome expectancy.

Staff Development in Science Education

The overall purpose of staff development is to develop a system in which teachers have the opportunity to regularly update and develop their teaching skills and knowledge (Joyce and Showers, 1988). The staff development needs in science education have had as one of their key components of developing the teacher's science content knowledge--and the teacher's prior knowledge--as part of the staff development process (Loucks-

Horsley, Kaptian, Carlson, Kuerbis, Clark, Mele, Sachse, and Walton, 1990). To this end, staff development programs in science frequently expend significant effort developing the content knowledge of teachers in the various disciplines of science (New York City Board of Education, 1984; Carroll County Public Schools, 1985; Thompson and King, 1999).

Staff Development in Urban Schools

With the desire for inquiry-based science in conflict with the observation that over 90 per cent of urban teachers typically teach through "direct instruction, lecture, rote and drill and practice" (ASCD Urban Middle Grades Network, in Hodges, 1996, p. 225; Silvertsen, 1993), the need for effective staff development is apparent. In addition to the pedagogical problems, content area preparation is likewise poor: only one-quarter of fourth grade public school students had teachers who reported that they were certified in the area of science (NAEP, 1998).

Elements from a retraining approach advocated by Bonja, Coogan, Lipman, and Rodgers (1986), primarily address the need for careful and comprehensive planning to meet the needs of the teachers, was recognized and implemented. Further, given the challenges of teaching in urban schools, the high dropout rates, and the complex and critical needs of teachers in these schools, the need for effective staff development is particularly important (Hodges, 1996). Undertaking staff development in urban schools offers multiple challenges. Several issues are critical to success in the urban educational setting. Among these concerns are that all stakeholders understand and work toward a common goal (Stein, Norman, Clay-Chambers, 1997). The lack of a shared vision disables the change process.

In an effort to institutionalize a new culture of staff development, the staff development programs were developed around groups of teachers with similar interests. Research indicates the value of these professional communities within urban schools (Bryk, Camburn, and Louis, 1997).

Project TEAM Approach to Staff Development

To address these issues and concerns, Project TEAM was developed through a partnership between Northern Illinois University, Elgin, IL School District U-46, and a parochial school located in Elgin, IL. Northern Illinois University, located in DeKalb, IL, offers a large teacher education program, with approximately 250 graduates yearly in Elementary Education.

School district U-46, in Elgin, is the second largest school district in the state of Illinois. It is a large and varied district, with a large number of students from underrepresented populations and a wide range of socioeconomic levels. In 1998, U-46 served over 34,000 students. The district reported that some 66 different languages were noted among U-46 students in a recent bilingual census. Approximately 26% of U-46 students are of Hispanic origin, 8% are African-American, 6% are Asian-American, and less than 1% are Native American (School District U-46, 1999). St. Joseph's, a Parochial School in Elgin, serves the same community, with an even higher (approximately 50%) number of the students enrolled as members of underrepresented populations.

Project TEAM--Teacher Education for the Approaching Millennium, represented an initiative designed to improve elementary education teacher preparation, content knowledge among both students and teachers, and the desire to better connect the

theoretical constructs from the science education community with the practical concerns expressed by students during an in-school clinical experience.

Conceived as a partnership bridging theory and practice in science education, Project TEAM recognized at the outset the challenges of connecting university models of best practice with the realities of the urban school setting. By involving the cooperating teachers in the beginning of the program and having them provide models of the best practice--ranging from pedagogy through lesson planning--a strong connection between methods course theory and classroom practice were achieved. This was part of an effort to apply the findings of Bryk, Camburn, and Louis (1997) towards the creation of an educational community.

The content materials used in the staff development were derived from the Operation Primary Physical Science (OPPS) program. OPPS is attempting to meet the challenge of providing exemplary staff development materials for elementary teachers and assisting them in the development of their science content knowledge. The physical sciences represented the area of emphasis for the OPPS materials, and a strong commitment to learning by doing--a constructivist approach--is evident throughout the program. Teachers learned fundamental physical science topics ranging from magnetism through sound by engaging in tasks that forced them to frequently ask the question "why?" and through investigation, obtain an answer. (OPPS, 1996a; 1996b).

The workshop facilitators, both faculty members from Northern Illinois University, provided the methods of teaching science portion of the workshops. The topics emphasized during the science pedagogy installments were science process skills, authentic assessment, and interdisciplinary instruction. Their efforts were, in large part,

directed towards moving teachers away from teaching in purely an expository fashion (ASCD Urban Middle Grades Network, in Hodges, 1996; Silvertsen, 1993).

The final component of the staff development program required the participating teachers to serve as classroom mentors, hosting university students for a three-week clinical experience. During this time, the Project TEAM teachers participated in a team-teaching experience with the university students, collaboratively implementing the lessons developed as part of the spring and summer workshops.

Science Teaching Self Efficacy and Outcome Expectancy

The overriding goal of Project TEAM was to provide teachers experiences and opportunities that build their confidence, capacity and expertise in teaching science and to share them with preservice teachers. To this end, self-efficacy provides a means of gaining insight into those affective issues that impact a teacher's ability to teach science. Teacher efficacy is the teachers' beliefs about their own capacities as teachers. The development of strong efficacy beliefs among service teachers would be one indication that coursework and practice impacts a teacher's classroom effectiveness (Housego, 1992; Hoy & Woolfolk, 1995). Previous studies examining this topic--that positive efficacy among science teachers is essential for the improvement of the profession--are numerous and emphasize a number of the same issues. From the broader literature of self-efficacy and modeling, there is abundant support for the approach used in developing more effective science instruction.

Outcome expectancy represents another construct that has been related to science teacher success. Where self-efficacy examines whether the teacher believes he or she can

be personally successful as a teacher, outcome expectancy examines teacher beliefs in terms of whether they can help children be successful learners.

Given this background, the purpose of this study is to examine differences in science teaching efficacy beliefs and outcome expectancy beliefs among teachers participating in Project TEAM workshops. This evaluation seeks to answer how participation in project TEAM influence teacher beliefs in terms of self efficacy and outcome expectancy.

Research Questions

The following questions provided the research questions for this study.

(1) The null hypothesis is advanced that there will be no changes in science teaching self efficacy as measured by the Science Teaching Efficacy Beliefs Instrument during the duration of the Project TEAM science education workshop.

(2) The null hypothesis is advanced that there will be no changes in science teaching outcome expectancy as measured by the Science Teaching Efficacy Beliefs Instrument during the duration of the Project TEAM science education workshop.

(3) The null hypothesis is advanced that among preservice teachers participating in the methods course/clinical experience, there are no significant differences between preservice teachers paired with Project TEAM teachers and those paired with non-TEAM teachers.

Method

The Science Teaching Efficacy Beliefs Instrument for preservice teachers (STEBI) was administered to all teachers participating in the project (Enochs and Riggs, 1990; Riggs and Enochs, 1990). Riggs and Enochs determined that the science teacher

efficacy instrument was both valid and reliable during trials administered during the early 1990s. Since that time, the STEBI has become an essential tool for science education research. The instrument offers measures of both self-efficacy and outcome expectancy. The self-efficacy scale indicates students' belief in their ability to perform a given behavior; the outcome expectancy scale indicates the students' belief that effective teaching (Enochs and Riggs, 1990; Riggs and Enochs, 1990) can change behaviors.

The Subjects.

The participants in the Project TEAM workshop were teachers interested in improving science instruction. They ranged in experience from one year to over twenty. Thirty females participated; three males participated.

Preservice teachers participating in the project numbered 32 in the case of the Project TEAM-paired teachers. Thirty-five other preservice teachers were interviewed at the conclusion of the semester to provide a basis for comparison between TEAM-paired and non-TEAM-paired preservice teachers.

Administration of the Instruments

During the duration of Project TEAM, STEBI instruments were administered to gain information about the teacher's beliefs at three points during the project's workshops. The first administration of the instrument (Time 1) took place during the initial meeting between the teachers and the workshop facilitators. The second administration of the instrument (Time 2) took place at the close of the workshops devoted to content knowledge development. The final administration of the STEBI (Time 3) was given at the close of the workshop, when teachers had completed both

science education pedagogy workshops and had completed the science units they were to teach with their preservice teacher.

Findings were tallied though an ANOVA procedure to compare means between groups. For this study, n = 33 participants.

A survey was developed and administered by the project co-directors to evaluate differences between student experiences after their participation in the clinical experience.

Results

The results of the STEBI instrument are summarized below in Table 1. Results compare the self-efficacy and outcome expectancy beliefs of teachers participating in Project TEAM at three different points during the series of workshops.

Table 1.

Science Teacher Efficacy and Outcome Expectation Data

Measure			Mean Difference	Significance
Efficacy	Time 1	Time 2	2.125	.039*
	Time 2	Time 3	4.500	.002*
	Time 1	Time 3	6.625	.001*
Outcome	Time 1	Time 2	2.313	.084
	Time 2	Time 3	2.000	.055
	Time 1	Time 3	4.312	.007*

* The mean difference is significant at the .05 level

Self-Efficacy Measure: As summarized in Table 1, teachers experienced a significant increase in science teaching self-efficacy during each phase of the project. The null hypothesis is rejected.

Outcome Expectancy Measure: As summarized in Table 1, teachers experienced a significant change in their outcome expectancy only between the first and final administration of the STEBI instrument. The null hypothesis is in part rejected.

Table 2.

Preservice Teacher Self-reports

Question	Measure	TEAM Section (mean)	Non-TEAM Section (mean)	Mean Difference	Significance
1.	Role of supervisor was critical	3.667	2.300	1.367	.000*
2.	Helpfulness of clinical experience	4.667	4.800	-0.133	.354
5.	I had a good working relationship with my clinical supervisor	3.200	3.367	-0.167	.687
8.	I will generally teach science effectively	4.033	3.633	0.400	.056
9.	I will generally teach reading effectively	4.300	4.067	0.233	.165
10.	I will generally teach social studies effectively	4.167	4.000	0.167	.206
11.	I will generally teach language arts effectively	4.200	4.167	0.033	.246

* The mean difference is significant at the .05 level

For the preservice teacher survey results, a significant difference exists only in terms of the perceived role of the clinical supervisor. In this instance, the null hypothesis is rejected; in terms of all other measures, the null hypothesis is accepted, as there was no significant difference between the mean scores.

Interpretation of Findings

In terms of science teacher self-efficacy, participants found themselves more efficacious after participating in each phase of the project. Participation in the content knowledge workshop, besides improving their content knowledge, improved their self-perception of their ability to teach science to their students. This is consistent with findings from studies on science teaching self-efficacy, that enrollment in staff development programs can improve science teaching self-efficacy.

Participation in the science pedagogy/unit creation component of the project likewise increased both their science-teaching knowledge and their sense of self-efficacy with respect to science teaching. This is also consistent with studies related to increasing science teaching self-efficacy. Increases in science teaching self-efficacy for both components of this staff development workshop imply its success by that measure.

A more intriguing finding is associated with the outcome expectancy measure. Rather than finding a significant increase in this measure during each phase of the project, it is the combination of *both* the science content knowledge and science pedagogy experiences that resulted in a significant change in this measure. This suggests that for teachers to increase their beliefs in how they can help students to improve their ability to learn science, teachers benefit from a combination of *both* content knowledge and science pedagogical knowledge. Independently, the workshops are helpful

experiences; collectively, they represent a much more powerful experience. This is information that can benefit all staff developers in science.

For preservice teachers participating in the Project TEAM experience, they recognize more so than in the other group of preservice teachers a significance for the role of the clinical supervisor, performed in the case of Project TEAM by the cooperating teachers themselves.

Seeking patterns among the students enrolled at NIU and taught by the same science methods instructor—but *not* interacting with the Project TEAM teachers led to the observation that students enrolled in the Project TEAM section tended to have higher levels of satisfaction in terms of the relationship with the student and the student teacher.

Question posed of students: "When a student does better than usual in a clinical, it is often because the cooperating teacher exerted a little extra effort." Based on responses ranging from "Strongly agree" to Strongly disagree," students paired with the Project TEAM teachers gave a higher average score than did students in a corresponding section of the science methods course (3.67 for Project TEAM students; 2.3 for other students).

Despite the nature of the relationship between the Project TEAM teachers and their role as clinical supervisor , students conversely found that they derived more useful feedback from an individual serving as the clinical supervisor who had a primary role as a university instructor. This may be due to this individual's previous experience as a clinical supervisor more than a reflection on the ultimate quality of the feedback from the Project TEAM teachers. Scores of 2.83 for Project TEAM paired students and 3.37 for students in the other section of the methods course were reported. This is the only area in

the entire survey in which the Project TEAM students rated their experience significantly lower than their peers in another section of the methods courses.

Project TEAM students also reported a higher level of contact with their cooperating teacher, with an average number of visits of 3.54 per student compared with 1.00 for students in the other section of the methods courses.

Finally, students in Project TEAM feel better prepared to teach science from an inquiry-based perspective than do students in the other section of the methods course, with average scores of 3.57 for the Project TEAM group and 3.21 for the other clinical group

Further Commentary

These measures of science efficacy have currently been administered to two groups of elementary education students. One group of students will work with the Project TEAM teachers; the other group of students will work with another group of cooperating teachers during a mid semester clinical experience. Having the same science methods instructor controlled their experiences. Findings from the students in terms of how their efficacy and outcome expectancy evolve based on their respective TEAM/non-TEAM placements will provide further information to inform and develop this model of staff development.

This is important to those who suggest that a position favoring only science pedagogy or science content is appropriate. The key finding of this study--that it is the *combination* of content and teaching skills--that provides the optimum arrangement. The combination of the content and pedagogy represented a much more powerful experience than either of the two components of the project presented in isolation.

The ultimate consumers of improved instruction and improved teacher preparation are students in elementary classrooms. A reasonable extension of this project would be to investigate the knowledge gains of students enrolled in Project TEAM teacher's classrooms.

The final comment of the authors is to affirm that the approach used during the Project TEAM experience was valuable to the teachers who participated. Both aspects of the project--the content knowledge component and the pedagogy component--were helpful to teachers in the project.

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Author Note

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Appendix

Survey instrument used with preservice teachers is attached.

Last 4 digits of SSN	_ _ _ _		Name (optional)	______________
Section Fall 2000	P3 (Elgin)	P4 (Kaneland)		
Gender	M	F		
For students in Section P3:	Was your cooperating teacher the same person as your supervising teacher?		Yes	No
For students in Section P3:	How many times did your supervising teacher observe you teach?		______	

Feedback from Clinical Placement

Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA	=	STRONGLY AGREE
A	=	AGREE
UN	=	UNCERTAIN
D	=	DISAGREE
SD	=	STRONGLY DISAGREE

1.	When a student does better than usual in a clinical, it is often because the supervisor exerted a little extra effort.	SA A UN D SD
2.	I found the clinical experience to be very helpful	SA A UN D SD
3.	When a student does better than usual in a clinical, it is often because the cooperating teacher exerted a little extra effort.	SA A UN D SD
4.	When a student is successful in a clinical setting, it is due in large part to their relationship with their instructor(s) on campus.	SA A UN D SD
5.	I had a good working relationship with my clinical supervisor.	SA A UN D SD

6.	I received helpful feedback from my clinical supervisor.	SA A UN D SD
7.	I believe that my instruction improved based on my experiences during my clinical experience.	SA A UN D SD
8.	I will generally teach science effectively.	SA A UN D SD
9.	I will generally teach reading effectively.	SA A UN D SD
10.	I will generally teach social studies effectively.	SA A UN D SD
11.	I will generally teach language arts effectively.	SA A UN D SD
12.	I have developed effective management strategies during my clinical experience	SA A UN D SD
13.	Based on my clinical experiences, I will be able to make use of performance-based assessments.	SA A UN D SD
14.	Based on my clinical experiences, I feel better prepared to teach in an interdisciplinary fashion	SA A UN D SD
15.	Based on my clinical experiences, I feel better prepared to teach science from an inquiry perspective	SA A UN D SD

The most important thing I derived from my clinical is....

SCIENCE AS A WAY KNOWING: USING READER RESPONSE AS A MEANS TO CONSTRUCT A PERSONAL UNDERSTANDING OF SCIENCE LITERATURE

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> Literature is a special way of knowing *only* if one accepts the fact that it *is* a special way of knowing, only if the reader lets the piece evoke feelings and trigger deep personal memories and associations. (Blake, nd)

Purpose

The purpose of this interactive session was to present and model a literary technique, called reader response, as a means of engaging students in the construction of understanding and the creation of personal meaning of science literature. Similar to "Literature as a special way of knowing" (Blake, n.d.) constructing personal meaning and understanding of science through reading literature allows us to move beyond content knowledge and to focus on the implications and applications of science to one's life. Science as a way of knowing allows us to embrace science as a relevant, meaningful, and useful endeavor, and allows us to link our own experiences to the literature to create personal meaning.

Theoretical Framework

A constructivist framework of teaching and learning science is embedded in the current fabric of science education reform. Implicit in this framework is the understanding that learning is not an isolated endeavor, but a process that is actively engaging. In constructivism the learner pulls from previous experiences, applies this knowledge to new experiences (usually teacher created), juxtaposes old and new experiences, and then constructs or reconstructs a personal understanding. A constructivist framework also embraces a collaborative, social process, where

learning and understanding are done within a community of learners. Thus, learning is mentally and physically engaging as well as a socially collaborative endeavor.

Just as constructivism is counter to a traditional behaviorist, empiricist paradigm of teaching science (Goodlad, 1984, cited in Oakes, 1990; Novak, 1991; Shymansky and Kyle, 1992; Yager, 1991b), reader response theory is opposite to a logical-mathematical (Gardner, 1985, Havelock, 1963), a paradigmatic (Bruner, 1985), or a rational/scientific means of knowing in responding to literature (Blake,n.d.). Traditional literary response has a longstanding, systematic formula for students to follow (Blake, n.d.). They include 1) Placing an emphasis on the text as text; 2) Finding the "correct" meaning of the text (typically the teacher's meaning); 3) Using a systematic, concrete, inductive, "scientific" method to interpretation; 4) Sharing criticism only with the teacher; and 5) Analyzing *parts* of the literary piece, yet viewing them as an "organic whole" (Blake, nd).

Such an approach to literary response is reminiscent of Lemke's (1990) "stylistic norms" (p. 131) of talking science, where students are to be explicit and technical, avoiding colloquial, metaphoric, and figurative language. We propose, as Lemke does, that these stylistic norms of talking, writing and responding to science sets science in opposition to human experience, and exempts learning "from social processes and real human activity" (Lemke, 1990, p. 134). These stylistic norms, therefore, continue to "mystify" the process of literary understanding, whether it be from a Robert Frost poem, George Schaller's *The Last Panda*, or Rachel Carson's *Silent Spring*. We agree with Lemke that these norms "veto" the techniques of communication that are "necessary for engaging the interest of an audience" (p. 134). Table I provides a comparison of how traditional literary response and reader response differ.

Table 1.

Objective (Traditional) Literary Criticism Versus Reader Response

Objective Criticism	Reader Response
1. Emphasis on Text as Text	1. Emphasis on Reader's Response to Text.
2. Reader finds "Correct" Meaning. Close Reading for Purpose of Getting Content Knowledge only.	2. Reader Creates Personal Meaning.
3. Approach is systematic, concrete, inductive, and "scientific." (Traditional critical apparatus)	3. Feelings are Allowed.
4. Analyzes parts of literacy piece but view them as an organic whole.	4. Memories and associations are encouraged.
5. Usually shares criticism with the teacher only.	5. Shares responses with others in learning community.
	6. Intuition is Invoked.
	7. Close reading techniques are used to substantiate the personal response.
	8. Reader comes to understand her response as a reflection of distinct personality.

Relevance to Science Teacher Education

As a means for creating personal understanding of science literature reader response is relative to current discussions in teacher preparation. For example, Korthagen and Kessels (1999) suggest that we, as teacher educators, should focus our teaching efforts on "reflective approaches," where students have considerable opportunity to explicitly link their experiences to their developing notions of what it means to teach and learn. Bryan and Abell (1999) echo the same sentiment in their discussion of the development of a teacher's professional knowledge, or stance (the relationship of their teaching to student learning), and the crucial link between reflection and the teacher's practice. They wonder: "How do we help them to articulate, analyze,

and refine their beliefs about teaching and learning?" (p. 172). In presenting and modeling reader response as a means of scientific knowing, we allow students the opportunity to pull from previous experiences, link these experiences to the literature, and to construct their own meaning of the science content in the literature. We also allow them to apply their understanding of this content to life in and outside the classroom.

It becomes apparent that to improve teacher preparation and thus the teaching and learning of science, we may consider alternatives in the way we prepare teachers and the way we engage them in literary understanding. Reminiscent of Schaller's statement regarding the objectivity of scientific research: "Any biologist who observes a tiger, gorilla, panda, or other creature and says he or she has done so with total objectivity is ignorant, dishonest, or foolish" (George Schaller, *The Last Panda*, 1993, p. 105), reader response allows for an affective, an emotional, even a subjective component of learning, and provides opportunities for students to reflect and engage in a socially collaborative environment, one that they can then help to construct and employ when they are teachers in their own classrooms.

Reader Response Components

Figure 1 provides the general structure of reader response. Key to the response process is allowing time and opportunity for the initial response. Next, students can articulate feelings and memories that link to the text. Figure 2 proposes additional responses for the students, ones where they construct personal meaning and value for themselves. Responses can therefore become understood as a reflection of each student's distinct personality.

Figure 1.

General Categories of Writing for Reader Response.

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1. Initial Response: An initial, immediate response written upon completion of the text.
    a. Key: Emotional, intuitive response.

2. Feeling Response: Affective
    a. Focuses on asking the question of "how do I feel about this?"
    b. "I" has a big role in the response.

3. Memory Response: Relational
    a. What does this remind you of? Any experience, young or old, that reminds you of what you read.
    b. Allows memory to inform understanding.

Reader Response Samples: Pre-Service Elementary Teacher Interns

Context

The following responses are samples collected from thirteen pre-service teacher interns enrolled in an environmental science class conducted at the Harford Glen Environmental Education Center (The Glen) and part of a Professional Development School (PDS) at Towson University, Towson, Maryland during the fall 2000 semester. The PDS is a two-semester, one-year model. Teacher interns were immersed in the elementary school culture at the very beginning of the school year (September 2000). Interns had a minimum of one full day of teaching in the elementary classroom and a maximum of three consecutive teaching days towards the end of the semester. In addition, two required courses, reading assessment and general curriculum, were conducted at the elementary school site.

Figure 2.

Other Responses and Issues to Consider

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1. Judgment of Subjective Value: Judgment of Importance
    a. Importance to Whom?
    b. What is meant by "importance?"
    c. Important Word, Passage, Feature?
        1. Supported with passages from reading: criteria for you.
    d. Linked to Perceptions, Feelings, and Memories.

2. Close Reading: A traditional means to literary response
    a. Done AFTER other responses.
    b. Used to *Substantiate* Initial Response(s)
    c. Used to *Discover* why you responded the way you did.

3. Creation of a Classroom Community: Interpretation as a Communal Act.
    a. Group Value and Validation.
    b. Enhances community authority.
    c. Involves Social Knowledge and Social Skills

Written Responses to "The Perfect Integration of Panda and Bamboo" from The Last Panda by George B. Schaller.

Following are written responses to a brief passage from The Last Panda. This passage was used to initiate reader response and to allow ample classroom opportunity to share writings and to ask questions of clarification and/or concern. The interns read the passage, immediately responded in writing, shared responses in small groups (three to four interns), and then came together for a full class discussion. Student samples are categorized as outlined in Figure 1.

Intuitive Responses

Links to Biology: Animal Behavior and Ecology

I thought it was a very colorful piece. It was very descriptive. The story is of a panda in her own environment and how she interacted in such a smooth yet methodical way. She knows her surroundings and has everything she needs, such as food, water, her mate and a place to bar her children. Even though her environment is simple she is comfortable. She can navigate her territory with ease, even while eating. She knows where he boundary is by the different trees. She can even tell when a male has been there. She does sense confrontation when

her home is invaded with the sound of an ax and moves away to avoid it. She is the essence of nature itself. She is quiet and peaceful and in perfect balance with her surroundings, she supports them and they support her. (Myia Johnson, 9/15/00)

Raising Questions of Morality

Very emotionally provoking in how it was written. Devastating this creature is living in a false sense of security. Her instincts tell her that she is safe, provided for, at "home". However, her "home" is being destroyed little by little. Where will she go? She knows that her place is where there is bamboo, but what about when that is gone? What right do we have as humans to take away the natural habitats of animals? If done to us, it would be in court, in the media, books would be written, and movies made. What hypocrites we are! (Marie Bull, 9/15/00)

Cynicism: To Good to Be True?

I was waiting for it. Establishing the perfect tranquil scene only to destroy it. This is an accurate portrayal of an animal in a closed environment. She has everything she needs with in 3000 feet radius. However, man is always lurking close behind. (Paul Marcantonio, 9/15/00)

Feeling Responses

Typical Response: Anger, Sadness, and Disgust

I feel embarrassed that humans can be so cruel. This panda did not bother us, yet we feel so powerful that we have to go in and take her universe. I feel sorry for the panda and her life that is being chased away. Why do we feel so big that we can just go in and ruin another organism's home? (Julie Spellman, 9/15/00)

Atypical Response: Feeling of Peace

This passage makes me feel peaceful. I became the animal and felt the peace and serenity that comes with being in harmony with nature. I felt like all of my senses were taking in the scenario in my mind's eye. It also made me feel like I was an outsider (from the human perspective) and like I wanted to preserve the memory (and even the reality of such a thing) from invasion by those that were in the process of destroying it. To me it felt very fragile. (Myia Johnson, 9/15/00)

Memory Responses

Memories from Childhood

I remember playing hide and go seek with my cousins and how I would always pretend to be the animal. I used to hide in the bamboo patch pretending I was a panda. It was difficult to be found and caught by my cousins. I remember eating the sweet shoots and bitterstalks just to try them. (Bo Dunlab, 9/15/00)

I remember seeing my aunt when she had her second child. She was in the hospital and her child was on her chest sucking. It again felt like I was an outsider

and I could see the balance and connection between mother and daughter. The child was getting substance from the mother and the mother was receiving the love and bond that only exist between mother and child. It was a delicate and fragile balance that I believe should be preserved. (Myia Johnson, 9/15/00)

This kind of reminds me of the innocence of children. Everything is simple and comes easy to them (well most of them). Just like the panda life was there for her to live, she had her food and she had her surroundings. There wasn't much work involved. (Susan Heller, 9/15/00)

Often times my memory concerning the environment goes back to a commercial I saw in the seventies. I was in elementary school at the time. A Native American in a traditional dress is on a hilltop looking out over what should be nature but it is a landfill. The camera zooms in on a single tear streaming down his face. No words are necessary. The meaning has stuck with me since then. (Sarah Roberts, 9/15/00)

Judgment Responses

Constructing Personal Meaning

The main important thing in the article was the fact that animals rely on certain things to survive-the panda needs bamboo. When their food supply is depleted, they will slowly die off and the world will lose another precious animal. (Laura Tine, 9/15/00)

I see the quote in the first column bottom of the page, "Within a circle of 3000 feet was her universe, all that she needed: bamboo, a mate, a snug tree den in which to bear young." That is not much space at all but man will never allow it. (Paul Marcantonio, 9/15/00)

Descriptive Writing and a Sense of Reality

The one thing that stood out the most was the idea that the panda's life is very calm and peaceful. I know that they are endangered species. I think the article was written to help to understand the panda's need for bamboo and to raise our awareness of the animal. The last paragraph shows the reality of the endangerment of the pandas by pointing out that someone is chopping something down near the edge of the bamboo forest. That is scaring the pandas up the ridge. (Stacey Auth, 9/15/00).

Human Intervention, Destruction, and Environmental stewardship

This passage is setting the picture for all habitats being ruined around our world. "Within a circle of three thousand fee was her universe, all that she needed: bamboo, a mate, a snug tree den in which to bear her young." This really creates the whole meaning of the story. Organisms are finally at ease and peaceful, not harming anyone and their habitat is being destroyed constantly. (Julie Spellman, 9/15/00).

End of Book Responses to Silent Spring.

The following responses were written upon completion of Silent Spring. At this stage of the reader response process the interns were asked to focus their writings on the articulation of the worth, the value and a sense of personal meaning of the text. What is evident in these responses is the sense of overlap among the categories. There appears to be no artificial separation between the initial, feeling, and memory responses and the construction of personal meaning and value. As represented in the samples, the interns often began with initial responses, pulling in feelings and memories and then using these to make a statement of value.

Initial Response

Initial Response Tied to Feelings and Science Content

My initial responses throughout the entire book have always referred back to my feelings of Carson's strength as a person. She is not afraid to tell it like it is and she is not scared to tell the truth. Her research backs her up although people will still deny it. ... As I read on in this book, I grew angrier at the fact that many people who were causing the problems constantly defended themselves and took no responsibility for their actions. "This is an era of specialists; each of whom sees his own problem and is unaware of or intolerant of the larger frame into which it fits." (p. 13).

The Cartoon Book mentions how protein in foods becomes less concentrated in a food as it goes down the food chain, but chemicals become more concentrated. Carson mentions milk, seafood, beef, etc ... as foods that all contain some sort of chemical. I really felt sick after reading the following quote: "To find a diet free from DDT and related chemicals, it seems one must go to a remote and primitive land, still lacking the amenities of civilization." (p. 179). Finally, I feel sad and scared about the chemicals that are carcinogenic. Cancer has hit my family hard and I can't believe that things like weed killers and insecticides containing arsenic can cause cancer. Dr. Hueper, as quoted by Carson says, "The goal of curing victims of cancer is more exciting, more tangible, more glamorous and rewarding than prevention" (p. 241). My final word: disgusting. (Julie Spellman, 10/20/00)

Memory Response

Author Title: Eyes Wide Open

I would like to be a mother someday soon. As a future mother I think about the state of the world and the state of our future world. . . . I have wonderful memories of growing up on a mountain in central Pennsylvania. I remember the

lush Mountain Laurel growing around us, playing hide and seek in a forest of baby hemlocks, catching crayfish in the stream, and my parents waking me up at three in the morning to watch from our window, a bear playing with her cubs. I want to share the same beauty of nature with my children and I am concerned that they will not have that opportunity. (Sarah Roberts 10/10/00)

Application, Meaning, and Value

Application to the Teaching and Learning of Science

One of the most important aspects of teaching, especially in science, is that you want your students to relate the concepts that are learned to real world experiences. This is what the theory of constructivism is all about. Constructivists follow the instructional 5-E model. . . .Constructivists believe that learners need to build their own understanding of new concepts and apply them to their own life. Reading *Silent Spring* allowed me to complete this process. The book made me look at the big picture of the environment and how everything is linked together in interrelated cycles. This book changed my view on the environment and my place in it.

Throughout the book as I gained knowledge on the subject, I was able to explain why all of these problems happened. Everything that occurred kept coming back to the big idea that our environment is made up of interrelated cycles that work together. I something is altered from one cycle, then all of the other cycles are affected. For example pesticides were used to control insects so that crop yields could be raised, but these pesticides got into the ground water and endangered the plants, animals, and humans.

I am now able to extend my knowledge gained from reading *Silent Spring* and apply it to things that are occurring in our environment now. For example, the spraying that is being done in Baltimore City to kill mosquitoes that might contain the West Nile Virus. The first thing that came to mind is what chemical are they using and what affect does it have on the plants and animals. The research done on the chemical used shows that it is only harmful to bees. So that's good right because no on likes bees? Wrong, the bee population is already lower than needed which makes pollination lower and affects flowers. ... and we are in another cycle of animals dying. (Lisa Mutillo, 10/20/00)

Using Reader Response to Explore the Nature of Science

Our aims in this exploratory study were several. We wished to engage pre-service students emotionally and personally in worthwhile science writing, in this case, a short but evocative selection from George Schaller's The Last Panda and Rachael Carson's whole book, Silent Spring. For their short, intuitive responses to the two pieces of writing, the students were instructed not to worry about

the 'correctness" of sentence structure, punctuation, and even spelling. Even more importantly, they were urged not to be restricted by a supposed "correctness" of what they wrote, certainly not of what they thought the meanings of the pieces were or what the teacher considered the meanings to be. Essentially, we urged them to "create," not "find," their own individual, personal meanings.

As we examined the student responses, we noticed that they responded in two categories. First, they flourished in a classroom environment free of teacher restrictions and displayed all the elements of Classroom Reader Response. They responded freely, immediately, and intuitively. They reacted emotionally to what they read, and they effortlessly and tellingly related their reading to their own real life experiences through what we call "memory responses." In a surprising fashion, several of the students reflected on the nature of their responses, a high level intellectual act, a meta-linguistic—or meta-scientific—skill, if you will.

The other category of responses dealt with the distilled essence of the "nature of science," observation and inference. The evidence of observation was slight, but since the prompts asked for short, intuitive responses, then the lack of extended observation—evidence or cataloging of concrete details—might be expected. With respect to inferences, the students uniformly were not tentative in making their inferences, conclusions, and moral judgments about the content clearly and decisively known. It is interesting to note that the students judged with no inhibitions the morality of situations described in the science writing. None, however, judged the value of the writing itself, a common form of evaluation in literary criticism.

Where to next, after this exploratory study? Since one of our aims was to provide elementary school teachers, both pre-service and in-service, with many joyous experiences with worthwhile science writing through Classroom Reader Response techniques and training in the elements of the Nature of Science, we shall provide future teachers with many more examples of valuable science

writing. Since the other major aim was to ensure that elementary school children come to experience the wonders of the natural world and perceive the study of science as a gateway to the beautiful and wondrous world of nature, we shall use valuable picture books with primary grade children first to simply observe without intervention how they react orally and in writing to accurate science writing, beautifully presented. Later, as the children become comfortable with their personal, intuitive responses, we shall provide prompts—in the children's own language—which guides them toward the basic elements of scientific knowing—observing carefully and inferring confidently and boldly.

Here are some of the books we shall be having the children—and their teachers—read and respond to.

Carle, Eric. 1997. *A House for Hermit Crab.* New York: Simon & Schuster Books for Young Children.

This beautifully illustrated book is filled with opportunities for children to sharpen their observation skills. Carle says, "his book is about beauty, nature, symbiosis and adjustment to growth and change."

Carle, Eric. 1998. *Hello, Red Fox.* New York: Simon & Schuster Books for Young Children.

In this lovely picture book, children learn about Johann Wolfgang von Goethe's theory of the three primary colors—red, blue, and yellow—through actual experiments with vibrantly colored illustrations of creatures and objects.

Martin, Jacqueline Briggs. 1998. *Snowflake Bentley.* The Caldecott Medal Winner. Boston: Houghton Mifflin Company.

In this book, "gracefully told" and brought to life in "lovely woodcuts," the writer and artist give "children insight into a soul who had not only a scientist's vision and perseverance, but a passion for the wonders of nature."

Further Considerations

Reader response allowed these teacher interns to read science related literature not strictly for content understanding but for the construction of an emotional, affective meaning as each related the text to her or his life. If teachers can construct multiple meanings of science text, meanings that have relevance and evoke memories of their own lives, what is the potential in allowing elementary students to create their own scientific understanding of age appropriate science related literature? How can we link science to the language arts, allowing students access to scientific understanding while at the same time "demystifying" the processes and products of science. In a true constructivist sense how can children use literature to aid in the construction of understanding and application of science in their everyday lives? These questions, and many more like them, are the focus of continued studies into science as a way of knowing.

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GETTING TO THE FOURTH YEAR

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Incorporated in 1993, SciMath^{MN}, a statewide, public/private partnership has worked in Minnesota to increase the educational achievement and participation of all Minnesota students in science and mathematics. It has done so by promoting standards based policy; professional development and practice; and, public awareness and engagement. SciMath^{MN} staff serve as project managers within each of these areas. Cyndy Crist is the project manager of SciMath^{MN}'s Transforming Teacher Education Initiative that focuses on the preparation of K-12 science and mathematics teachers.

The Transforming Teacher Education Initiative, a group of faculty from higher education and K-12 schools, was developed to work with state policy makers in aligning state and national standards for K-12 students and teachers. The vision of the collaborative was to begin the process of transforming teacher education in mathematics and science so that teachers will be prepared to teach according to the vision of present and future national standards and will be prepared to continue learning new content and new ways of teaching throughout their professional career. In 1998, the Teacher Research Network (TRN) grew out of this initiative.

As a result of SciMath^{MN}'s participation in the Salish II project, five teacher preparation institutions came together to explore the possibility of a joint investigation into the status of Minnesota's beginning teachers of science and mathematics. The TRN collaborative met several times during its first year to investigate the research process used by Salish I and II and

their findings, as well as other scholarly work related to teacher assessments. These included the INTASC portfolio project and the Praxis exams used by our state. The primary purpose of TRN was to devise a plan of study and instruments to assess the current status of our beginning mathematics and science teachers that we define as those in their first three years as teachers. Additionally, TRN encouraged the collaboration of science and mathematics education researchers and provided those researchers with financial support and on-going professional development opportunities. Dr. George Davis from Minnesota State University Moorhead and Dr. Patricia Simpson from St. Cloud State University serve as co-directors of the Teacher Research Network.

Operation of the Network

The TRN group meets two to three times a year. The meetings provide an opportunity for researchers to discuss the instruments, their findings and raise questions and concerns about the process to date. Discussions have centered on each instrument, how it has worked, the results, what the results tell us about our research questions and whether or not modifications are needed in instruments or procedures. When instruments are changed, training on the instruments and their analyses are provided at the meetings. Meetings are also a time for professional development related to issues associated with research on teaching and learning. Each university is required to send representatives to these meetings and ensure that all university team members understand what is to be done.

Each university has a team composed of full-time faculty at the teacher preparation institution. Each team has a contact person who is responsible for the efforts of their institution and for maintaining communication with the directors of the project. All TRN members serve as researchers investigating beginning science and mathematics K-12 teachers. Members may also

choose to serve the TRN collaborative as members of special interest groups. These groups work on development of individual instruments, compilation of data, or interpretation of data. Institutional teams apply annually to SciMath^{MN} for grants to financially support the work being done by their team members. Grants primarily support teacher and faculty stipends. SciMath^{MN} also provides support to the network as a whole for meetings, speakers, staff and other resources necessary to keep the running.

University teams agree to the use of a common set of instruments and procedures chosen for use each year. Every team collects data from individual teachers, no more than two teachers per researcher, as outlined by the network's study procedure and returns the data to the special interest groups responsible for its analysis. Once the common research goals of the organization are met, individuals or teams may additionally choose to investigate additional research questions by using the same instruments with other student populations. Currently the TRN network includes nine institutions. The initial five universities (Minnesota State University Moorhead, St. Cloud State University, University of Minnesota Duluth, Gustavus Adolphus College and St. Mary's University) were joined in year 2 by four other teacher education institutions (The College of St. Scholastica, St. Thomas University, Southwest State University and the Minnesota State University Mankato). During the 2000/2001 academic year, faculty at each institution will administer four instruments to mathematics and science teachers in their first, second or third year of practice. Approximately 50 of these teachers will be in their second year with the project.

Development of the Research

The first year of the project was considered to be a multi institutional pilot of instruments and administration procedures developed by Salish I. Our preliminary research question asked,

do beginning science and mathematics teachers have beliefs and practices aligned with state and national standards? Four instruments were used with teachers at each university site. CLES, the Constructivist Learning Environment Survey, uses 42 items with versions for teacher and students. It looks at beliefs concerning learning environment in five sub-scales. STAM, the Secondary Teacher Analysis Matrix, uses teacher videotapes to categorize teacher style. The TPPI, Teachers Pedagogical Philosophy Instrument, elicits teacher statements about self, teacher actions, students' actions, the classroom and personal philosophy. STEBI, the Science Teaching Efficacy Belief Instrument, is another survey to examine teachers' efficacy with two sub-scales. All instruments were administered to science teachers only in year one.

Findings from year one indicated that two of the instruments, CLES and TPPI need simplification for use by our group. STAM was replaced because it did not adequately align with Minnesota's emerging state teacher standards. All instruments were modified for use with mathematics teachers. Administration and coding procedures were clarified among group members.

Current Practice

In year two, research questions were revised and nine institutions participated in TRN. Analysis was completed for forty-nine beginning teachers of science or mathematics. Individual researchers were responsible for recruiting teachers, completing teacher observations, interviews, and the analysis of data for each individual teacher. Due to the amount of data collected on a teacher, the group decided that each researcher would follow only two teachers within a year. A teacher profile was developed to summarize teacher data. Each profile used a similar format, providing descriptions of the participants' teaching in five categories (I-Knowing Science Content, II-Knowing Pedagogy, III-Knowing Students, IV-Establishing a Learning Environment,

V-Professional Development that correspond to our research questions. Also included was a section that described key demographic information about the participants and pertinent contextual elements such as school settings, course information, and community type. A meta-analysis was then completed on the teacher profiles. Four categories, elementary science, elementary mathematics, secondary science, and secondary mathematics were used for analysis. All profiles within a subgroup were analyzed by a single researcher with knowledge and expertise in the area corresponding to the descriptor for each subgroup. Profile analyses were reviewed and confirmed by two additional reviewers for each set of profiles.

Multiple sources of data were used to develop individual profiles for each teacher. Every teacher and his/her students completes a modified Constructivist Learning Survey the CLES(2)20, the teacher completes the Science Teacher Efficacy Beliefs Instrument (STEBI) and a demographics instrument describing the teacher, school, classroom and students. Individual researchers complete their own personal demographics instrument and conduct two classroom lesson observations using the Minnesota Science Teacher Observation Instrument (MNSOTI). This instrument was developed by TRN to correspond with new INTASC based, Board of Teaching requirements for teacher licensure. For each lesson observation, MNSTOI requires a pre observation questionnaire, a focused observation and a follow-up questionnaire and interview. Teachers select two lessons for observation. One lesson is teacher identified as being inquiry and the other focuses on conceptual development. Finally, teachers complete an extended taped interview with the Minnesota Science Teacher's Observation Instrument (MNSTI). This is a modification of the TPPI. These instruments provide TRN with three sets of lenses to view the teacher; student beliefs (CLES(2)20), teacher beliefs (CLES(2)20, MNSTOI questionnaires, and MNSTI) and researcher observations (MNSTOI). The information from

these data sources was used to answer five questions: 1) What does the beginning teacher know about science? 2) What does the beginning teacher know about pedagogy? 3) What does the beginning teacher know about students? 4) What does the beginning teacher know about creating learning environments? and, 5) How is the beginning developing as a learner? In each instance, "know" refers to the knowledge, beliefs, skills and actions of the teacher. The instruments also helped to answer a sixth research question regarding the conditions in which these teachers work.

Preliminary Findings

Data analysis for year two is till in progress. While the MNSTOI provided a standard description for each of the five categories, interpretations of these categories varied to some degree with different researchers. Consequently, there was some unevenness in teacher profiles due to the lens through which key points were captured by the profile authors, the amount of evidence taken from the raw data, and the observations that were excluded from the profiles. Another concern was that at each level of analysis, there was a loss of resolution; the data became coarser as it filtered through initial collection, preparation of profiles, and the meta-analysis. These concerns will be addressed as instruments and procedures continue to be fine-tuned. What follows are samples of preliminary findings from the meta-analysis of the 1999/2000 elementary and secondary science teacher profiles. The profiles proffered some interesting trends and themes while raising a number of questions rich in potential for further study. The scope of this paper will not permit a full elucidation of all findings. Consequently, a sampling of the findings while be shared as well as a snapshot of some key evidence supporting these findings. We recognize that these are tentative findings and caution the reader not to extend these findings beyond the data set.

Findings from Elementary Teacher Profiles

There were 14 elementary teachers and student teachers in this study. All were observed teaching science lessons to elementary aged children. The student teachers in this study were both undergraduate and graduate students completing their student teaching for initial Minnesota licensure in elementary education. The schools in which most participants taught ranged from small town schools to larger suburban schools in Minnesota or North Dakota. A few of the universities in this network are close enough to the borders of neighboring states that many student teachers and beginning teachers are placed out of the state. The classrooms contained students of mostly Caucasian ethnicity that is representative of Minnesota students with the exception of the metro Minneapolis/St. Paul area. The diversity described within the classroom setting was not racial diversity as much as it was behavioral challenges, intellectual variation, and ADD/ADHD. The vast majority of the participants (both student teachers and novice teachers) voiced their lack of confidence teaching science. During classroom observations two teachers demonstrated misconceptions about the concepts they were attempting to teach their students. Most teachers/student teachers chose science lessons in areas of their interest and comfort level. Most also chose to teach hands-on lessons using science kits (FOSS Kits). They described the lessons from such kits as "hands-on" and "inquiry" lessons. Most taught the lessons as presented in the kits. One student teacher modified the lessons from the FOSS Kit to provide learning experiences for her students that she felt were more inquiry based and required more higher order thinking from students. A strong assertion can be made that most participants commonly equated hands-on lessons with inquiry based learning in science although most could not clearly define inquiry science learning. All agreed that hands-on activities help students learn science more effectively than the traditional lecture approach. All participants believed that

students learn well from hands-on activities and they attempted to provide such activities for their students. Student teachers easily used language (such as constructivism, facilitated learning, guiding student learning, etc.) that reflects current standards for effective practice in teaching science. Most participants see themselves as guides, facilitators or coaches in the classroom. However, as in the anecdote above, this view was not consistently demonstrated during classroom observations of science instruction. Some teachers were quite teacher-centered in their approach and focused on covering the material for students to learn. Many of the teachers and student teachers appeared to do a great deal of teacher telling in their instruction. It is suggested that participants' perceptions of what they are doing in the classroom differ from what is actually happening in the classroom on a daily basis. The participants in this study also fit their views of constructivism and hands-on learning into a direct teaching model. One teacher described students listening to her discussion of a science lesson as a hands-on activity because the students were actively taking notes. It seems clear from this initial analysis that beginning teachers believe activities are good in science classrooms. As educators, we have made that crystal clear. What this analysis suggests is that the majority of beginning teachers stop with the activity. Very little evidence of placing the activity in a more global context or assessing the hands-on activity exists. Running counter to the notion of being a constructivist teacher, neither student teachers nor novice teachers used methods that provided them with students' prior knowledge about the science in the lessons that were observed by the researchers. Some teachers mentioned that they used the KWL method to obtain prior knowledge and to learn about students' interests, but not all demonstrated this strategy during their lessons. To some the prior knowledge seemed important to the lesson being taught, and to others it did not. For a true constructivist teacher, knowing the students' prior knowledge is the critical starting point. It is

interesting that student teachers appeared to most consistently Relate the Minnesota Frameworks to their lessons and in the interviews. This may be because it is a requirement during their student teaching, or because they were reflecting the focus of learning the standards in their university special methods classes. Experienced teachers, not just the ones teaching out of state, mentioned the Frameworks, but offered no observable evidence of their use. As for the nature of science, all participants struggled with the definitions of fact, hypothesis and theory. Many initially thought they had a good understanding of the terms, but began to question that understanding when they were asked to provide examples of each term. Many suggested that they knew that the knowledge base of science or a paradigm in science might shift from time to time.

Findings from Secondary Teacher Profiles

There were 19 secondary teachers profiled in year two. Seven were student teachers, eight were first year teachers, and four were second year teachers. Subjects taught by these teachers included high school biology, earth science, physical science, and chemistry. At the middle school life, earth and physical science teacher were observed. Nine participants were female and ten were male. Some participants were teaching in Catholic schools, but most were in public schools. Three are pursuing master's degrees. Some were teaching in urban settings while a number of the participants were in large rural districts. Most practicing teachers held licensure in the content areas they were teaching for this study, except two who were teaching on variances. Some participants brought considerable applicable experience. One brought thirteen-year of college teaching experience, while another spent seven years working as a scientist for a major drug company. Another worked as a state biologist before returning to school to complete her teacher licensure program. Many participants held a weak conception of the nature of science

often revealed in misconceptions about inquiry. This study regards elements of inquiry to include: asking questions, generating hypotheses, designing experiments, conducting experiments, using controls and variables, generating data, manipulating data, making generalizations from data, defending conclusions, developing models [physical, mathematical, mental], using models, arguing from data and replicating experiments. Within the scope of the data collected, many failed to see inquiry as a scientific approach to a question and instead equated it with any hands-on activity. One student teacher believes scientific inquiry occurs "when students are allowed to explore and develop an understanding of a concept through hands-on activities and questioning which is directed by the teacher."(Frank profile, p.1). Others defined inquiry as an exercise where students enter into an Activity blind, responsible to discover some information they could have been told in advance but were not, essentially a form of discovery learning. A second year teacher describes inquiry as... "It's going in and discovering a subject or an object, instead of just being told what it is. So it's the students going through a series of activities or events so that they come up with some idea of what the topic is, or what the method is of whatever." While a first year teacher indicated that a lot of what she teaches "is left for the students to fill in the missing pieces and they do that through inquiry." (Betty profile, p.3) Two of the participants indicated they used less inquiry in life-science courses than in physical science courses. One indicated that life science simply lends itself less to inquiry than physical science, perhaps because his understanding of physical science content is stronger than his life science knowledge. (Frank profile, p.3) The other (Lars) pointed to time constraints in life science courses as the reason for doing so. When defining inquiry, some participants pointed to issues of student control where students are empowered to ask questions and seek answers to their own questions. Marv's interpretation of scientific inquiry is to "allow students to take

control of researching a topic, be it either a lecture item or a lab." (Marv profile, p.1) Whether or not the school or school district has embraced the Minnesota Graduation Standards appears to be a significant factor in determining our participants' use of the state standards. Indeed, a number of participants (Frank, Lars, Olaf, and Angela) commented that whether or not they used the graduation standards was influenced greatly by their school or district. One of the themes that emerged from our data related to the degree of control accorded to students, the power they hold in the classroom, and, their opportunities to have a voice in the operation of the classroom and the learning processes that occur there. Not surprisingly, there appears to be a wide range of discourse opportunities observed in this regard with a trend towards a correlation between amount of classroom experience and degree of student voice. Most of the more experienced teachers in our study tended towards a student centered discourse while some of those with limited classroom experience tended towards a teacher centered discourse. The small size of our sample, particularly the limited number of second year teachers in our study, points to the need for further study in this area. Future longitudinal data may be very helpful in this regard. Participants are aware of an impressive array of learning strategies to engage their students. Some of these included jigsaw cooperative learning, models, use of newspaper clippings, discussion techniques, lab investigations, dissections, debates, role plays, demonstrations, and videos, among other strategies. Factors that influenced participants' selection of learning strategies included their own experience as a student, recommendations of experienced teachers, time constraints, efficiency and effectiveness of methods chosen, connections to student lives, and pace and variety of classroom activities. Disappointingly, how well the activities suited the learning goals for that lesson, a fundamental element of standards based education, was rarely sighted.

Future Directions

We are currently in our third year of data collection. This year we will add several new teachers to the project and follow others for a second year. New participants and follow-up studies continue to raise new questions about teacher practice. At this point, we are satisfied with the instruments and our plan for data analysis. We believe more work is needed with TRN participants to assure that we have common meaning for terms used in the study. We have learned many lessons about the process of collaborative research and feel it can provide important findings about beginning teachers to the science education community as a whole. Further study is warranted before refined assertions will emerge from the data. Nonetheless, the current results of this study have spawned a wealth of further research questions rich in potential and more focused in scope. We believe that the emerging research will mature into insightful assertions that can help us pursue excellence in Minnesota science teacher preparation.

PROFILE CHANGES FOR TWO STUDENTS IN A (MATHEMATICS, SCIENCE & TECHNOLOGY EDUCATION) PRESERVICE TEACHER EDUCATION PROGRAM WITH CONSTRUCTIVIST VIEWS OF TEACHING AND LEARNING

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The term constructivism is used broadly throughout education. Constructivism has been used in reference to a research paradigm, a sociological position on learning, a philosophical position on knowledge, and in describing pedagogical approaches to teaching. Among the various kinds of constructivism, one is educational constructivism (Phillips, 1997b). Educational (or psychological) constructivism differs from other forms in that it focuses on the ways in which human beings individually or collectively justify their understanding of material objects and mental representations of the world (both social and psychological worlds). Of special interest to educational constructivism are the ontological and epistemological characteristics upon which knowledge is founded. In this research, we documented changes in these characteristics as preservice teachers completed the university-based course work leading to teacher certification in science. We were also interested in the implications that changes in ontological beliefs and epistemological commitments had on preservice teachers' conceptions of themselves as teachers and their conceptions of students as learners.

This research focuses mainly on educational constructivism which we subdivide into the categories of individual, radical, and social, depending on the unique ontological, epistemological, and pedagogical commitments of each (see Kwak, 2001 for a comparison of versions of educational constructivism). In spite of all the varieties of educational constructivism, there is little argument that it is an overarching paradigm in contemporary science education or one of the major influences in present day science teacher preparation (Matthews, 1994). While

it is common in our experience to hear teacher educators mention different forms of constructivism during their instruction, there is little evidence to support the claim that preservice teachers understand different versions of constructivism beyond using it as jargon. There is also little evidence to support the assumption that a particular version of constructivism should have implications for a preservice teacher's ideal view of teaching and student learning. This is to say that there needs to be evidence to indicate if preservice teachers themselves believe they would be able to teach in ways that are consistent with different versions of constructivism. In this study we investigated changes in preservice teachers' profiles of educational constructivism as they participated in a science teacher education program, and the implications of those beliefs the preservice teachers expected to have on their teaching.

Before investigating the implications of any version of educational constructivism on student learning, which we believe are inseparable from teaching, we needed to understand the extent to which teachers can internalize ontological beliefs and epistemological commitments with respect to educational constructivism. And, if they could internalize these characteristics, how did they change during the university-based portion of their teacher education program? For us, a preservice teacher's views of teaching and learning should be founded on these two characteristics. In the section that follows we describe continua for ontological beliefs and epistemological commitments that we will use throughout the remained of this article.

Theoretical Overview

Addressing changes in scientific knowledge, philosophers of science strive to explain the objects of human thought, namely, the material existence of the world and objects in it (ontology). Ontological beliefs can be placed along a continuum from realism to idealism. At one

extreme on this continuum, *realism* asserts that there is an existing material world apart from, and independent of, human experiences and human mental activity. Statements consistent with realism maintain that science can discover a human-independent world, including the world of unobservable entities such as electrons, viruses, and tectonic plates (Matthews, 1994; Nola, 1997). Realism presupposes a correspondence between mental representations and the objects they represent in the world (Bickhard, 1997). Ontological positions labeled as realism are consistent with views of learning such as Piaget's individual constructivism and Vygotsky's social constructivism (Phillips, 1997b; Ernest, 1995; Geelan, 1997; Gergen, 1997).

The realist stands in opposition to *idealism*, a position advocated by Gergen's Social constructionism and other radical social positions on constructivism influenced by sociologists of science. Idealists maintain that either there is no world outside of human experience and that the world, including human experience, is constituted only by the human actions of discourse or theorizing about the world. Along this line, in some forms of idealism, scientific knowledge is justified through social interactions, depending on consensus or dissensus within a community of individuals but not against actual observations or reality. According to idealism, our representations, regardless of their individual or social origins, are all we really have (Matthews, 1994; Nola, 1997; Bickhard, 1997). Furthermore, idealism leads to a relativist epistemological position in that there are no rational criteria whereby some ideas can be judged correct and others incorrect. There is no mechanism for choosing between competing theories or views (Matthews, 1994; Bickhard, 1997).

A third ontological position between the realist and idealist positions is the *radical* ontological position advocated by von Glasersfeld. This position is neutral with respect to the role of reality (Ernest, 1993). von Glasersfeld contends that while there is realty, there is no way

to directly access that reality. That is, there is no "extraexperiential reality" against which constructions of knowledge could be evaluated (Matthews, 1994, p. 149). Radical constructivism denies the possibility of any certain knowledge as a representation of the world, not the existence of a physical world.

Epistemology is a theory of the nature, genesis, and warranting of subjective [or shared human] knowledge, as well as a theory of "truth." It is essentially about "how the epistemic agent--the knower--knows about the world" (Ernest, 1995). According to Greeno (1989), thinking and learning are influenced by an individual's beliefs about the nature of knowledge and learning (i.e., a personal epistemology). The continuum for epistemological commitments we use to describe educational constructivism includes social constructionism's *Relativism*, Radical constructivism's *Fallibilism*, and Individual constructivism's "*Piagetian*." A forth epistemological position taken by traditional pedagogical practices is represented as *Absolutism*.

At one end of our continuum, Fallibilists maintain that scientific knowledge is tentative and controvertible, and can never be regarded as beyond revision. Our knowledge is always provisional in that it is always open to change through processes of confirmation, elaboration or revision. Fallibilism is "an epistemological position that is opposed, on the one hand, to relativism and, on the other hand, to absolutism" (Matthews, 1994, p. 37). Relativists hold that knowledge is constructed (and justified) within a particular community. Following from Kuhn's notion of science, relativists maintain that no reliable comparisons can be made between competing views since different paradigms construct different natural universes. At one extreme end of this position, some social constructivists would contend, "the natural world has a small or non-existent role in the construction of scientific knowledge" (Phillips, 1997b, p. 190).

In contrast to Fallibilism, Absolutism (also known as Objectivism or Foundationalism) holds that our current theories are absolute and unimprovable. [Progressive] Absolutists hold that over the course of history, science approaches truth (e.g., Truth) more closely. That is, the replacement of old scientific theories by new ones is a progressive step toward ultimate truth about the world and how it works (Ernest, 1998). Moreover, scientists produce knowledge in science because they have faith in progressive absolutism, and tend to believe that "increasingly accurate approximations can be made to account for the world and how it works" (AAAS, 1989; Harding & Hare, 2000).

On the other hand, an epistemological preference closer to the middle of our continuum, what we call "Piagetian", emerged from the interview data we analyzed. Piaget admitted that an "external reality is playing a role in constraining and shaping the views we construct about it" (Phillips, 1997b, p. 184), but "nature does not uniquely and unequivocally determine" our interpretations or constructions of the world (p. 170). This epistemological commitment emphasizes that "science is a creative human endeavor which is historically and culturally conditioned, and that its knowledge claims are not absolute" (Matthews, 1994, p. 139). This perspective on knowledge incorporates participants' statements related to epistemological issues. This Piagetian epistemology preference is well aligned with the position advocated by Piaget's individual constructivism (see Kwak (2001) for exemplary quotes supporting each ontological and epistemological category).

Conceptions of Science Teaching and Learning (CSTL)

Internalizing the ontological beliefs and epistemological commitments that underlie any view of educational constructivism, preservice teachers would be in a position to act in accord with the pedagogical implications that result from changes in these beliefs. These actions might

take forms such as sensitivity to a learner's previous knowledge, diagnostic teaching, attention to metacognition, and so on. We argue that exposing preservice teachers to issues of learning that does not adequately address the ontology and epistemology of constructivism would provide them with a set of terms but would not challenge previously held views of pedagogy. Therefore, science teacher educators would benefit from knowing if there was change in a preservice teacher's understanding of constructivist ontology and epistemology, change that should result in dissatisfaction with their views of instructional methods that have "usually been composed primarily of exposure to traditional science instruction" (Stofflett, 1991, p. 5). Along this line, developing a base of knowledge about change in preservice teachers' pedagogical perspectives would be instrumental in "providing a framework for considering both the learning processes involved in changing their conceptions, as well as providing a framework for designing instruction that facilitate those changes [in their instruction]" (Hewson & Kerby, 1993, p. 5). That is, such knowledge would provide fundamental insights for designing preservice models that could help preservice teachers acquire more appropriate conceptions of science teaching.

Overall this study sought to answer the following questions:

What profile of constructivist beliefs--in terms of ontological beliefs, epistemological commitments and pedagogy (e.g., CSTL)--can be constructed for preservice teachers during the period of this study? That is, do the ontological beliefs and epistemological commitments of preservice teacher's change as a result of coursework in their teacher education program and, if so, how?

A larger study associated with the results reported here investigated change in sixteen preservice teacher's knowledge about constructivism and the reasons for any change (Kwak, 2001). Constructivism was a major theme in the preservice instruction these students received as

will be demonstrated later. In the larger study, each preservice teacher's self-reported understanding of educational constructivism was analyzed in terms the ontology, epistemology and conceptions of teaching science supporting a particular view of constructivism. It is important at this point to reemphasize that there are epistemological and ontological differences between different versions of educational constructivism--individual, radical, and social constructivism. As an analytical framework, the main tenets of each version of educational constructivism (Phillips, 1997a; Matthews, 1994, 1998) were examined with regard to the philosophical notions of ontological beliefs and epistemological commitments. This, in turn, leads to different pedagogical perspectives (Phillips, 1997a; Ernest, 1995) depending on which version of constructivism is under consideration. That is, each version of educational constructivism should result in different teaching practices depending on the philosophical positions taken towards ontological and epistemological issues.

For example, one version of educational constructivism is individual constructivism. This version is characterized as ontologically realist and epistemologically Piagetian position. An individual constructivist should accept the (ontological) reality of an external world (Geelan, 1997). That is, as Piaget stated, "external reality is playing a role in constraining or shaping the views we construct about it" and "we only construct those that are in some logical sense 'isomorphic' with nature," not copies of the real world (Phillips, 1997b, p. 184). For Piaget, a person exists as a real biological entity in a real physical world who constructs mental structures (schemas) to deal with that world through internalizing actions on or about the world (Ogborn, 1997). According to this position, public knowledge as well as personal knowledge of science is "a carefully checked construction" rather than discovery of a "real" world that exists independent of cognizing experience (Driver & Oldham, 1986).

Furthermore, although knowledge is constructed based on experience, these human constructions do not approximate an inherent order in nature. The epistemological commitments for this version of constructivism emphasize that "science is a creative human endeavor which is historically and culturally conditioned, and that its knowledge claims are not absolute" (Matthews, 1994, p. 139). "Many of the constructivist teaching programs, such as Driver's at Leeds University and much of the conceptual change pedagogy, fall within the individual-objectivist" range (Geelan, 1997, p. 21). Based on the premise that existing ideas are critical to future learning, students' intuitive ideas in science are known to vary from the 'ways of seeing' adopted and found useful by the scientific community (Duit, 1993). Along this line, Driver and Oldham's pedagogy suggests that students be enculturated with scientists' ways of interpreting the world.

Driven by the epistemological perspective described above, an individual constructivist seeks harmony between scientific and students' conceptions (Driver, et. al. 1994). Individual constructivist pedagogy emphasizes active engagement of students in their own learning processes taking into account the impacts of prior knowledge or conceptualizations on new learning. Therefore, instructional experiences planned by a teacher should help students reconcile any differences between their ways of thinking and those of the scientific community. Moreover, an individual constructivist presumes that children have to be introduced to the public, symbolic, and created world of science and that they should internalize these concepts. That is, "learning science is essentially a process of enculturation into the ideas and models of conventional science" (Driver, 1989, p. 103). Therefore, scientific understanding requires initiation into scientific traditions and this initiation needs to be intentionally provided through a science teacher's instruction.

A second version of educational constructivism is radical constructivism. Ontological beliefs associated with radical constructivism are a radical position on ontology--there is a reality but there is no way to directly access that reality--"no extra-experiential reality" (Matthews, 1994, p. 149). In other words, what radical constructivism denies is the possibility of a representation of the world that is certain beyond the individual. Therefore, radical constructivism can be assigned 'an ontologically neutral position' with respect to the external world (Ernest, 1993). A radical constructivist is also characterized by a Fallibilist epistemology--the philosophical view that scientific knowledge is tentative and can never be regarded as beyond revision. Radical constructivists take an instrumentalist approach to scientific knowledge. Sharing roots with skepticism, this view of knowledge maintains a "functional fit" with the prediction of a subjective experiential reality. That is, knowledge is checked by the extent to which constructions fit with our experience in a coherent and consistent way rather than by a match with an external reality (see Kwak, 2001 for a complete discussion about different ontological, epistemological commitments and pedagogical beliefs advocated by three different versions of educational constructivism).

Methods

To document preservice teachers' understandings of educational constructivism we used the notion of a profile containing ontological beliefs, epistemological commitments, conceptions of science teaching and learning (pedagogical beliefs), and explainers of change (or lack of change). Borrowing from Mortimer's (1995) notion of a profile change for individual science concepts, we view each preservice teacher as having a *constructivist profile*--a profile composed of his or her views on the nature of reality, reason for justifying knowledge, and conceptions of

science teaching and learning. Changes in one or more of the components in this profile for the preservice teachers in this study were traced over time. We view the process of change in the overall profile in terms of changes in a conceptual ecology--that is, change is not viewed as the exchange of one belief for another but rather as a shift in components of the overall profile. In other words, even though preservice teachers are able to talk about different versions of constructivism, they could remain attached to their prior views of teaching and learning for a variety of reasons, such as emotional attachment or the low status of an alternative. When change does occur for a preservice teacher, that process will more likely be consistent with the notion of conceptual capture proposed by Hewson (1981). In this article we will demonstrate the feasibility of analyzing changes in constructivist profiles for preservice teachers and the implications these changes have on their views of teaching and learning.

Constructivist profiles for two students enrolled in the science teacher preparation program are described below. In particular, we sought to identify changes in the ontological and/or epistemological characteristics for each preservice teacher as they completed the university-based coursework for their preservice teacher education program. We also sought to identify the implications of changes in these characteristics on their developing views of teaching and learning. Data were collected over the first three terms (each term lasting 10 weeks) of course work during four in-depth interviews. The interviews were generally open-ended but included interview about instances on science teaching and learning, forced-choice questions containing a priori statements linked to various ontological and epistemological ideas, and the Constructivist Learning Environment Survey (CLES).

Before presenting our analysis of these data we begin by discussing the intent of the science teacher education program as communicated to us by faculty teaching in the program.

We then illustrate how data collected from the preservice teachers were used to produce constructivist profiles for the two preservice teachers presented here. Next, we discuss change in these profiles for each preservice teacher. We conclude by discussing the implications that findings from this study have for teacher education programs that teach constructivism as a significant theme.

Description of the Science Teacher Education Program

The science teacher preparation program we studied resulted in a Master's of Education degree after five terms (ten-weeks each) of full-time study. The study was conducted from initial enrollment in the program, when students were first introduced to the term constructivism, through the end of their university-based coursework, just prior to their internship with a practicing high school teacher. Based on statements in the course syllabi and responses to an email interview by faculty teaching in this program, this preservice science teacher education program advocated constructivist perspectives on learning. That is, the majority of faculty in the program stated goals or objectives of their course that were similar to the following: "to promote constructivism as a way of understanding how students learn concepts and as a teaching strategy for stimulating students' conceptual changes" (course syllabus, July, 1999). Syllabi contained required textbooks written by Brooks & Brooks (1993), Ernest (1995), and Tobin (1993), all of which address constructivism at a philosophical level. In addition, instructors for these courses indicated that they modeled what they believed to be constructivism, interpreting constructivism here as the teacher's perspective on how people learn. Providing students with the opportunity to participate in activities that were constructivist in nature, the faculty expected these preservice teachers to gradually change their views of teaching from that of a student's point of view to viewing teaching from a teacher's perspective (Vellom, personal communication, 2000). They

also wanted their students to plan and implement constructivist-based approaches in the field component of their preservice program.

We concluded this study prior to the student teaching internship, when the influences on our subjects shifted from those planned by the university faculty to those that arise as a result of working with mentor teachers in their school settings. Before examining changes resulting during the 'theory into practice' stage of a preservice teacher's development (e.g., changes due to internship with a practicing science teacher), it is desirable to investigate how each preservice teacher internalized the forms of constructivism taught to them by their education faculty. Although "the effects of a teacher education program appear to be erased by classroom practice" (Kagan, 1990), it is important to investigate preservice teachers' developing notions of constructivism to know if they are internalizing different forms of constructivism. Obviously, teacher education programs must first make students aware of the various forms of constructivism before these notions of learning can be applied in a classroom. That is, to realize constructivist pedagogies in the classroom, preservice teachers should know what constructivist views they hold, and how each is different ontologically and epistemologically before they try to apply that understanding during instruction. This study investigated preservice teachers' projected pedagogies. Following them into their student teaching and subsequent induction year(s) was not part of this study, although we recognize the importance of doing so in the future.

Subjects

In all, thirty-four students were accepted into this mathematics, science and technology teacher certification program and they were seeking certification to teach science. All completed the CLES questionnaire. Sixteen of the thirty-four students--eight females and seven males--were

interviewed four times each for the larger study. Of the sixteen participants in the larger study, five significantly changed ontological and epistemological beliefs and eleven did not (see Kwak, 2001). Profile changes for the five who did change also result in changes in their conceptions of science teaching and learning (CSTL). Because of space constraints, in this article we present profiles for only two preservice teachers--Rob and Ellen. Rob's case was chosen because he was aware that his ontological and epistemological positions should be consistent with his pedagogy. In Ellen's case, although her profile does illustrate significant change, she was not aware of these changes. In one sense, these cases represent the most desirable change in a profile in that they are consistent with the goals of faculty in this teacher education program. This is why they were selected for presentation here--they represent 'best case' scenarios. However, they are not representatives of the entire group since only five out of sixteen preservice teachers showed any change in their profiles.

Data Analysis

The four main components of a preservice teacher's conceptual ecology (e.g., ontological beliefs, epistemological commitments, CSTL, and explainers) were derived from four coded interview transcripts. We coded statements from each transcript in terms of four categories (i.e., ontological beliefs, epistemological commitments, pedagogical beliefs, and explainers) using the text unit function in NUD*IST. If a text unit applied to more than one category, it was placed in both. Each preservice teacher's constructivist profile was generated using the coding table function in NUD*IST that presents the number of text units coded at any set of sibling nodes. Each preservice teacher's overall profile consisted of three sub-profiles: an ontological belief profile, an epistemological belief profile, and CSTL profile based on the proportion of text units in that category. The proportion of text units in each category was then calculated as a

percentage of all text units for an interview. Each sub-profile was further divided into categories such as realist, radical, and idealist for the ontology sub-profile. The height of each segment in the ontological profile indicated the percentage of text units for each component. Finally, the change (or lack of change) in the number of text units coded for each preservice teacher's sub-profiles over time was recognized as changes in the heights of segments within that profile. Lastly, statements coded as explainers were examined for all transcripts. Explainers included statements in which preservice teachers commented on why change did or did not occur. Emergent categories for these statements included each teacher's past experience (e.g., their memory of previous exemplary teachers, schooling experiences, image of self as learner, academic history, and life path), the M.Ed. program (e.g., what was learned from coursework of their preservice program, field experiences, observations of other teachers such as the program faculty and their mentor teachers, and discourses with their peers), other background knowledge or statements of dissatisfaction (e.g., complaints about previous schooling experiences). Our analysis was verified through member checks with each participant after an interview. The final analysis included presenting each participant with our analysis of changes in his or her profiles throughout all interviews.

Findings

Each case study begins with a brief sketch of Rob's or Ellen's past experiences and a brief account of their personal history prior to entering the teacher education program. Subsequent sections elaborate on Rob's or Ellen's ontological belief profile, epistemological belief profile, and CSTL profile. In general, the characteristics represented by each sub-component in a profile are illustrated with appropriate examples from interview transcripts. In

the final section, we discuss the subjects' explanations (i.e., "explainers") for change (or lack of change) in their profiles.

Rob's Case

Past Experiences

Rob is a Mexican American male in his middle thirties. He enrolled in the preservice teacher education program with the intent to be certified as a high school biology teacher. His previous career experiences included working as a Spanish/English interpreter at children's hospital, as a regional Field Recruiter for a state Department of Migrant Education, and as a part-time biology instructor for undergraduate college students. In his application to the program he wrote about the need for teachers to provide "clear understanding and communication of information" to students. He also wrote that students' "resilience and enthusiasm, as well as their level of understanding are characteristics which can be found in most younger people if one is willing to take the time" to look. When applying to the program he indicated his desire to share his "enthusiasm for the natural world with seventh through twelfth grade students"--a fascination he had always had with the biological sciences. He also stated that he felt he could "offer a unique opportunity to engage the interest of students of all ages." He wanted to be a teacher who would "spark students' interest, through the use of everyday examples and applications which might seem to have greater bearing and relevance on their lives" (Rob, personal communication, June 1999).

Rob's Ontological Profile

Analysis of Rob's ontological profile following the first interview showed his preference for the realist ontological position. That is, for text units coded under the ontological belief

category, all (100%) were identified as belonging to the subcategory for realist ontology (see Figure 1). Asked to align his ontological beliefs with one of the forced-choice items during the first interview, Rob selected the a priori realist preference and stated that "[nature] does exist independently.... regardless of whether we do appreciate it or not. Those concepts are there for the grasping" (Rob, interviews 1 & 2). According to Rob, "there is a real world of material and other objects which exists apart from our theorizing about it." Rob's realist ontological beliefs were grounded in his science background. That is, the relationship of theoretical objects to reality was, for Rob, determined through his experiences with learning scientific knowledge. In his experience, when he understood a science concept, it had concrete existence for him. If a concept was unintelligible, it was "made up to explain why this is happening." In Rob's case, the plausibility of a theoretical element determines its physical reality. In a sense, Rob believes that for a conception to be true, it needs to be consistent with his worldview.

Preference for a realist ontological position was maintained in Rob's second interview (65% of all text units). However, Rob now offered some statements coded in the idealist ontological belief category during his second interview. Following this interview, Rob's profile included statements categorized into multiple ontological subcategories (i.e., realist, radical, and idealist).

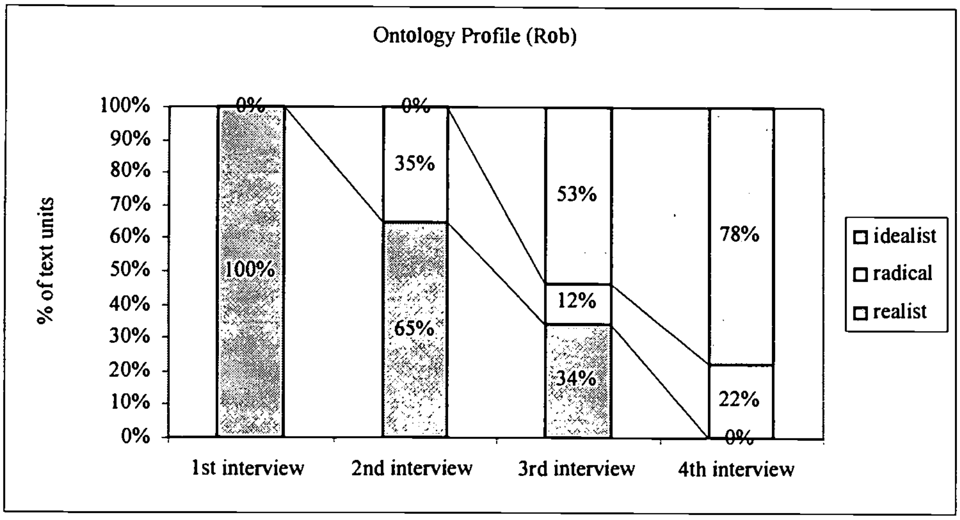

Figure 1: Rob's ontological belief profile

In the third interview, Rob offered statements of apparently contradictory ontological beliefs (i.e., realist and idealist) as follows: 34% realist, 12% radical, and 53% idealist. Regardless of the incompatibility of his statements, Rob's comments were distributed across all positions (e.g., realist, radical, and idealist). In the second interview, Rob's profile showed radical ontological beliefs as he acknowledged that our perceptions and our experiences constitute reality. When responding to the forced-choice questions in the third interview Rob offered multiple interpretations regarding the nature of the external world. For example, when responding to a question about his perceptions of the natural world independent of his understanding (i.e., a realist portion for ontological beliefs), his statements were consistent with von Glasersfeld's ontological assumption to the following degree: 35% of text units in the second interview, 12% in the third, and 22% in the fourth interview. Typical statements placed in this radical category for Rob included: "[since] we all have different filters, that's going to affect the way that we assimilate information.... You have your world of images and you never really have access to reality... Everything is a construct" (Rob, interview 3). According to Rob, each

individual constructs his or her own "subjective" reality by interpreting and perceiving "our daily laws and everything in different ways" (Rob, interview 3). While Rob's statements indicated that there is a reality that includes physical objects such as "stars, the sun and the moon," he also contended, "there is no way to directly access reality because of each individual's different internal 'filters'." This position is consistent with a radical ontological position.

Rob's ontological belief profile following the fourth interview was 22% radical and 78% idealist. As he read through the exemplary realist option presented during this interview, he questioned, "how do we know that there is a reality?" He further questioned the existence of a known reality stating: "reality is a subjective thing. My reality is different from your reality. I don't think there is one objective realty." Statements like this were placed in the idealist category for Rob. Other examples included: "the language, cultural beliefs, and social group that you grew up in and developed in are going to affect" how one perceives the world (Rob, interview 3). Rob's shift to an idealist position was further elaborated in the fourth interview as he articulated the roles that "cultural differences" and "our social interactions, and environments that we grow up in" determine "how we come to see the world" (Rob, interview 4).

Although it is not a new idea that "people can have different ways of seeing and representing their world" (Mortimer 1995), Rob's conceptualization of reality shifted dramatically from the first interview to the last. For example, when he talked about the existence of electrons, tectonic plates, and black holes, his ontological beliefs were grounded in a realist position. However, when asked to align his ontological beliefs with exemplary statements of realist, radical, and idealist positions through forced choice questions (see Kwak, 2001), his comments revealed a coexistence of different ontological assumptions and beliefs. Rob's perceptions of reality moved from one category to another depending on the contexts and

contents of the situation. Over the four interviews, his profile changed from solely realist to including varying proportions of radical and idealist ontology by the third interview. As Mortimer (1995) suggests, reasons for these changes can be found in the different prior experiences Rob received as a learner and in his distinct socio-cultural background. Factors that explain Rob's reasons for change in his ontology are discussed after analyzing his epistemological profile in the following section.

Rob's Epistemological Profile

Text units were coded within subcategories of absolutist, Piagetian, Fallibilism, and relativist for epistemology. Our focus when analyzing the interviews was to determine the foundations for Rob's views on scientific knowledge and truth. Rob was asked to discuss his ideas and to comment on forced-choice options describing different epistemological standpoints. As can be seen in Figure 2, Rob maintained a preference for a Piagetian epistemological position as the largest component throughout all interviews: 79% in the first interview, 76% in the second, 51% in the third, and 70% in the fourth interview. Statements indicating Rob's Piagetian position included: (a) "nature does play a role in shaping what we know about it because we base ourselves on phenomena that we observe [in nature] to create laws and explanations"; (b) However, nature does not "act as a constraint because people speculate and infer beyond what we can see" in nature; and (c) "I don't think there is ultimate scientific truth [although] there is a point where you integrate more and more things and you expand your base of knowledge but I don't know that there is an ultimate scientific truth" (Rob, interview 4). Rob rejected the possibility of obtaining "ultimate scientific truth" although he indicated that human beings are striving for it in our attempt to "come up with a dictionary of explanations for things that are happening" (Rob, interview 4). According to Rob, because "these [scientific theories and

explanations] are all our inferences, we don't really know what happens and we don't know if we can get to a true picture of reality and there is no final answer."

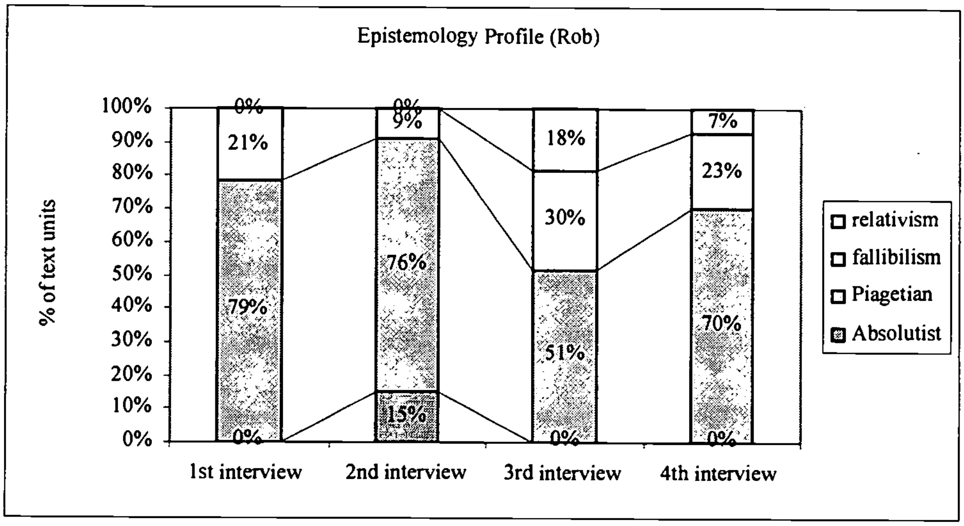

Figure 2: Rob's epistemological belief profile

After the first interview, Rob's epistemological profile was 79% Piagetian and 21% Fallibilism. Rob maintained the Fallibilist epistemological component in his profile throughout all interviews as follows: 21% in the first interview, 9% in the second, 30% in the third, and 23% in the fourth interview. According to Rob, "the world is always interpreted through your mind" (Rob, interview 2), and as "subjective beings [we] tend to interpret things subjectively... so objectivity is tough one" to achieve in science (Rob, interview 4). Accordingly, he acknowledged that "scientific truth is fallible and controvertible" (Rob, interview 3) and that "science should always be open to revision" (Rob, interview 4).

As was the case for other interviewees, Rob's epistemology was closely related to his ontology. For example, Rob had an absolutist epistemological component (15%) that matches (logically) with his realist ontological beliefs after the second interview (15% absolutist, 76%

Piagetian, and 9% Fallibilism). He stated that "[nature] does exist independently [and that] knowledge and those concepts are there regardless of whether we appreciate them or not" (Rob, interview 2). On the other hand, in accordance with statements about an idealist ontological perspective, Rob revealed a relativist epistemology during the third interview. In the third interview, we found apparently contradictory Piagetian and relativist epistemological positions coexisting in Rob's epistemological profile: 51% Piagetian, 30% Fallibilist, and 18% Relativist. From his relativist epistemology, Rob acknowledged that different socio-cultural communities (e.g., a Western community or an Amazonian native community) construct different realities. The acceptance of knowledge claims for people in these communities "depends on the culture and society" within that community (Rob, interview 4). Alternatively, according to Rob, a reality constructed by "someone who is a creationist with religious beliefs that are not accepting of evolution" would view the world differently from Rob's reality, his being one that is accepting of evolution (Rob, interview 4). Rob went on to say, "those are different realities" and "that cultural differences [affect how] people see things" (Rob, interview 4). After the fourth interview, Rob maintained his relativist epistemological position but to a lesser extent than in the previous interview. Following the final interview, Rob's epistemological profile featured the coexistence of three different epistemological positions: 70% Piagetian, 23% Fallibilist, and 7% Relativist.

In conclusion, Rob consistently maintained two components to his epistemological profile--Piagetian and Fallibilist. However, some of Rob's statements were coded in the relativist epistemological category. One important issue regarding changes in Rob's ontological and epistemological profiles is that he could transfer his ontological and epistemological beliefs to his views of science teaching and learning. That is, he was aware that changes in his ontological and epistemological beliefs did have implications for his actions as a teacher of science. His view

of himself as a teacher will be discussed in the explainer section after discussing changes in his CSTL profile in the following section.

Rob's CSTL Profile

A Conceptions of Science Teaching and Learning (CSTL) profile was constructed using categories of traditional, Piaget's Individual, von Glasersfeld's Radical, and Vygotsky's Social pedagogy. After the first interview Rob's profile was: 90% Piagetian and 10% traditional. Overall, he viewed the teacher's task as introducing "a certain core body of knowledge and certain standards" to students so they could construct meaning within the bounds of "certain standards" (Rob, interview 1). During the first interview Rob amplified his views of a good science teacher stating that a good teacher shows "enough connections between what students have learned in the science classroom and what they would see when they're walking outside of the classroom." This was necessary, according to Rob, so students would "see relevance to the subjects or applicability [to their lives]." Rob felt that it was important for his instruction to create strong connections between science and students' everyday lives, connections that would "make students think and stimulate students' interests [in learning]."

Following Rob's second interview his CSTL profile was 85% Piaget's Individual, 9% von Glasersfeld's radical, and 6% Vygotsky's Social. Having been introduced to different theoretical works on constructivism by faculty in the teacher education program by this time, Rob's profile changed such that he eliminated the traditional pedagogical perspective identified after his first interview. According to Rob, this change was due to discussions of conceptual change teaching and learning presented during the coursework in his teacher education program. Accordingly, his view of the role of a teacher shifted to:

See what's already there, what of the [students' ideas] that are there might not be what the teacher considers correct. You have to work with those preconceived notions and naïve conceptions, and build on those.... If I can help direct them in a certain direction to get over certain hurdles. (Rob, interview 2).

Rob wanted to "more or less direct students or put them on shortcuts that would avoid a lot of dead ends." He stated that not to do so would result in "you as a teacher doing them a disservice" (Rob, interview 2). Grounded in his epistemological beliefs that "knowing is a subjective sense making activity," Rob expected his students to "try to make sense of what they see, hear, smell, or what somebody tells them" (Rob, interview 2). Along this line, "the teacher must structure and facilitate learning environments with as wide a range of experiences as possible" to reach as many students as possible. In order to accomplish these instructional goals he "wouldn't necessarily completely exclude the lecture method because there are some people who [learn] better with that method" (Rob, interview 2).

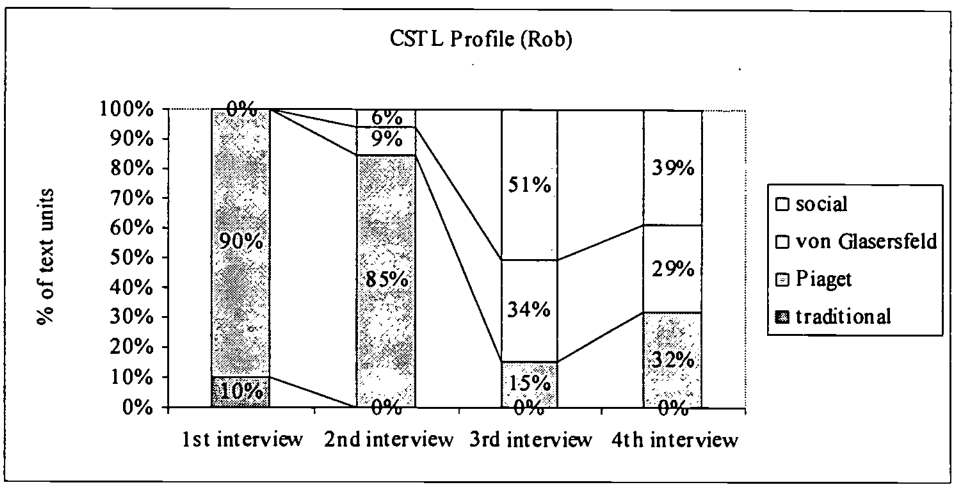

Figure 3: Rob's CSTL profile

At this time, Rob's view of teaching mainly focused on "making students see a relationship between science or whatever concept I am teaching them at the moment. And how that might apply to everyday situations or their lives." According to Rob, students "can find some interests or some applications which might help to make it more appealing to them and then get them to ask questions" (Rob, interview 2). An ultimate goal of Rob's science teaching was for students to "understand what is considered acceptable and not acceptable, how to present information, and how to express themselves." It was Rob's belief that this is "what students are going to be doing eventually when they are not in school anymore" (Rob, interview 2).

After the third interview, Rob's CSTL profile was 15% individual, 34% radical and 51% social. Although Rob still stated that "learning is subjective and a process of self-organization", he now included more emphasis on the importance of students reaching consensus in terms of their learning. That is, as a teacher, he would "tell students what the society [whatever society you are in] thinks is the best explanation. However, it's up to them [the students] to decide whether or not it is the best explanation for them" (Rob, interview 3). Moreover, for Rob, established scientific theories were no more than "a structure or a framework which makes it easier for you to relate to the world around you" (Rob, interview 3). Rob's view of science teaching shifted from having students 'exchange' their preconceptions with accepted scientific concepts, to having them know that "they can believe whatever they want to believe as long as they are open to other people's explanations and they can come up with justifications and rationale for their point of view" in the third interview (Rob, interview 3). To reach his goals, Rob's teaching would emphasize "on-going dialogue as opposed to conflict or an argument." He described himself as a "facilitator and supporter" who is "interacting with people, reaching

consensus, and encouraging students to explain why they believe something and to justify their interpretations" (Rob, interview 3). When asked to state his instructional goals Rob mentioned:

> To communicate the messages. To provide shortcuts. To give students a wide selection of things from which they choose what they personally find enjoyable or productive or useful, depending on what they want to pursue. To get kids to think for themselves, and to value and incorporate students' prior knowledge or what they bring with them to the classroom. (Rob, interview 3)

Following the fourth interview, Rob's CSTL profile was 32% individual, 29% radical and 39% social. Analysis of this interview showed a reappearance of an individual component in Rob's profile. Although Rob still believed, "teachers facilitate and support students to construct their own ideas," he firmly realized that as a teacher his role was to "link students and the scientific community. In a way, you help them interpret things from a scientific community back and forth until students have enough of a conceptual framework to do their own interpretations and go off on their own." Rob stated he still wanted "to clear up possible naive conceptions that students may have, to teach students to be independent thinkers, to have them question most things that they see and hear, including what the teacher tells them" (Rob, interview 4). This notion is also stated in the following:

> To facilitate, support students and help them to create their own ideas or their own interpretations and then kind of direct those interpretations a little along established lines.... [to] encourage your students somehow directed so that they reach that the same consensus reached in the general scientific populations. If they reach a completely different consensus then you have problems because there are certain accepted consensuses [sic]. (Rob, interview 4)

In the end, Rob's CSTL was consistent with his beliefs about the nature of scientific knowledge (i.e., his epistemological profile). That is, Rob contended, "you never know if [new information] will change what we are discussing, so you want to always leave them with an open mind to accept that there is nothing that is absolute or set in stone. [Science ideas] should be

subject to further questioning and possible modification" (Rob, interview 4). As a teacher, Rob believed that "the learning environment should include a range of experiences so that students know what is the most accepted theory but also know what are some of the alternative theories or alternative explanations" (Rob, interview 4). Rob also stated that "learning is a process of self-organization and knowledge is our attempt to explain what we observe" where "everybody brings their own experiences which we can't really share" (Rob, interview 4). According to Rob, "everybody's own experiences create that person [by] building plans in their head. Then they try to relate things in their head to the outside world based on the plans that they make" (Rob, interview 4). Grounded in his individualistic ontological beliefs (recall the Radical position for Rob described above) and his awareness of the fallible, tentative nature of knowledge, one of rationales for science teaching was to have students "understand why a certain interpretation is the most accepted and why it has the most evidence in favor of it." Furthermore, Rob "definitely wanted to encourage your students to explain and justify [their positions].... Whenever a person tells you some belief, you want them to justify, support it somehow, and articulate [the reasons for] it." Rob wanted students to leave his science class with knowledge of the criteria used to judge the validity of information--"how to explain for themselves and justify their positions" rather than with propositional knowledge of specific science content (Rob, interview 4). In the final analysis, he insisted, "the teacher must definitely know what is going on in the student's head and try to understand what the student understands" (Rob, interview 4).

General Characteristics of the Explainer Section

At the end of each interview Rob (and Ellen) was asked to explain what was most influential in forming his (or her) beliefs about teaching and learning, and what was most significant about the teacher education coursework or experiences during the program. Analyses

of data in this section focus on: (a) whether each preservice teacher was conscious of changes in his or her ontological and epistemological profiles, and (b) the extent to which each preservice teacher was conscious of the relationship between his ontological/epistemological beliefs and CSTL. It is important at this point to reemphasize that there are significant differences at the epistemological and ontological level for different versions of educational constructivism--individual, radical, and social constructivism. These differences should, in turn, result in different conceptions of science teaching and learning. To that end, our attention will focus first on an analysis of the explainers each preservice teacher mentioned for his or her belief changes, that is, their answers to 'why did your beliefs change (or not change)?'

Rob's explanations for changes

When asked to provide the most influential factors in helping form his beliefs about teaching and learning, Rob offered (a) university coursework--especially field experiences, (b) interactions with other fellow preservice teachers who showed him "there are many different ways of learning" through group work in the program, and (c) his family and other living situations wherein he "had a chance to hear and talk to them about how they teach and what their opinions are" (Rob, interview 4). What he has learned most throughout the university coursework is that "there are many different ways of learning and therefore there should be many different ways of teaching." This is quite different from "the [memorization type of teaching] he experienced as a learner" (Rob, interview 4).

A member check confirmed that Rob was not conscious of changes in his ontological and epistemological profile changes throughout the program. However, when reflecting upon his profiles after the last interview, he explained that his ontological beliefs "shifted towards the social sector," as a result of "interactions with peers and interactions in the classroom." Rob

stated, "passing through radical would not necessarily be the way to get from realist to social [idealist] zone." Aligned with his strong commitment to a Fallibilist epistemology, he stated that his "profile is dynamic" and "is probably going to continue to change constantly since it has obviously changed [since starting this teacher education program]" (Rob, interview 4).

He also acknowledged, "there is concordance between ontological and epistemological beliefs, and that is reflected over pedagogical beliefs as well." However, he didn't provided specific instances of this concordance. Likewise, when questioned about his awareness of different versions of constructivism he could not distinguish various versions of "weak, radical, and social" (Rob, interview 2). However, he clearly remembered that "social constructivism was ... Vygotsky perspective that would be that things are determined by the social context and you are going to learn based on the society in which you are developing" (Rob, interview 2). He expressed his understanding of different versions of constructivism best in the following:

> The ones I remember are weak constructivism, radical, and social. The weak, I believe, the only principle that they say is that learning has to be like a proper experience. It has to be something that happens to you. It's not passive. Learning is not a passive experience. So that would be weak constructivism. And radical constructivism is that plus the second one of somebody's principles, I can't remember what his name is, the guy who has those two principles. And, what was the second principle involved there, I can't remember right now what the second principle was. (Rob, interview 2)

Rob's ontological and epistemological beliefs were also consistent with how he viewed teaching and learning. Throughout all interviews, Rob moved away from realist ontology and towards idealist ontology. In doing so he insisted on a socially negotiated, culturally bounded representation of reality. Aligned with his radical/idealist ontological beliefs, Rob's epistemological beliefs were firmly grounded in the notion of "no ultimate truth" and no immediate access to the real world because of constraints on our perceptions, and culturally determined criteria of truthfulness. According to Rob, human beings "are trying to come up with,

say, a dictionary of explanations for things" that "we are constantly editing based on things that are happening" (Rob, interview 4). In another statement from Rob, we are "trying to collect pieces for a puzzle, or many puzzles maybe, and you're trying to collect pieces that make of these different puzzles [many different interpretations and explanations depending on the society and culture you belong to]" (Rob, interview 1).

Since Rob believed in the tentative nature of scientific knowledge, as a teacher he wanted to be a "link between students and the scientific community" (Rob, interview 4). Accordingly, he would present "what the society thinks is the best explanation, certain principles about which there has already been a consensus in the general scientific community." However, he also maintains that "it is up to the students to decide whether or not it's the best explanation for them." This statement reveals a radical characteristic in his epistemological beliefs that can be summarized as "everybody's own experiences create that person… students should know what is the most accepted scientific theory but also knows what are other alternative possible theories to something or alternative explanations." In the end, Rob indicated that his teaching needed to introduce students to "a consensus reached in the general scientific populations or how to do scientific inquiry or investigation" using "the accepted model for how to do things" because otherwise "students have problems" in surviving and continuing as members of a specific community--in this case, the "contemporary Western [scientific] community" (Rob, interview 4).

Ellen's Case

Past Experiences

Ellen is a white American female in her late twenties, requesting certification in Earth Science for grades 7 to 12. Ellen remembered that she was always a good student who "learned

by understanding and did what she was supposed to" (Ellen, interview 1). She also remembered she was "infamous for asking 'why' and saying 'I don't understand' when she was a student because she was "unaware that students were just given information and expected to swallow it." To this day, Ellen resented any learning environment in which she was merely provided information because it placed her in a "learning situation where she couldn't learn" (Ellen, interview 1).

Throughout her previous experience as a Peace Corp volunteer and a lobbyist in an environmental group, Ellen discovered, "how much impact she as an individual has on somebody else" and how much she "always wanted to be able to make a difference" in her community. Her experiences with a group of urban Gatos kids in the Peace Corp were "powerful and rewarding", and she could see "what happened when she had a group of kids under her influence, and how she could make them better people." Therefore, Ellen felt that she could utilize "two things that she was good at... an ability to help people feel more confident about themselves, and an ability to explain complex ideas or difficult ideas simply so people can understand them" (Ellen, interview 1).

Ellen's Ontological Profile

After the first interview, Ellen's ontological belief profile showed realist as the largest component (62% of the total text units) while 38% of her statements were coded as radical. Ellen began with accepting the existence of an external world that constrains what we can believe about it. Typical statements placed in the realist category for Ellen included: "there is a human independent world" and "people have discovered that theoretical objects exist." Ellen also acknowledged that it is possible for us to "totally misinterpret what the scheme of reality is," further explaining this notion as "even though we can describe [the real world] and make sense

of it … [our understanding] might not be right." Statements like these are consistent with the ontological perspective we described as realist in Kwak (2001).

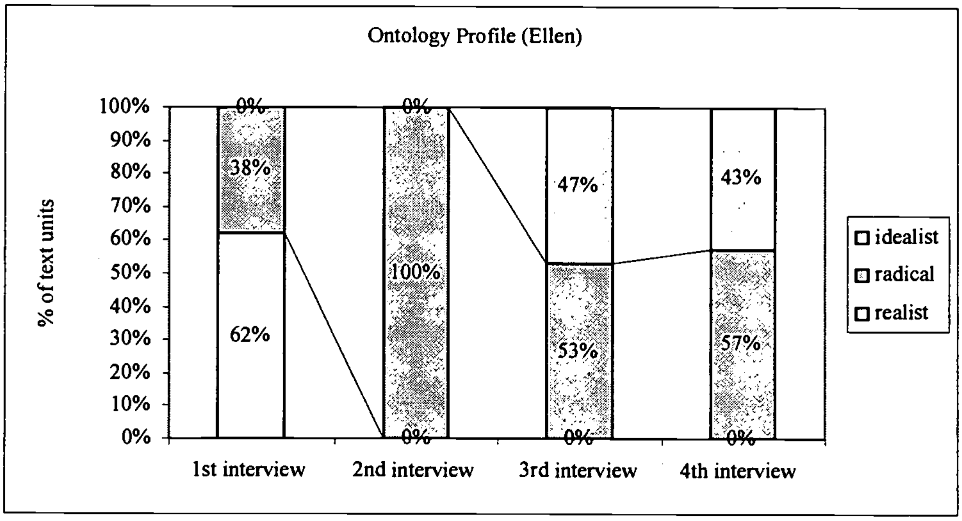

Figure 4: Ellen's ontological belief profile

Asked to select one of the forced-choice items during the first interview, Ellen chose the option representing a radical ontological position--or "a perspectivist" position in Ellen's terminology. Furthermore, Ellen expressed an "anti-realist" position in support for her choice, questioning her access to reality, in the following:

> So I think that our analysis of the real world is not necessarily describing what's actually out there. Even though we can describe it and make sense just like Newton's physics made sense and worked, it might not be right. So [the world of real objects do not exist independently of minds] well, this is a reality and we have an idea of what that reality is to each individual, but do we really see the real reality? Probably not. I am a perspectivist. (Ellen, interview 1)

Ellen contended that our knowledge of reality is never unmediated and that each individual constructs his or her reality mediated by a point of view or a particular set of personal experiences. These statements align with von Glasersfeld's ontological assumptions about reality and were placed in the radical ontology category. When asked about the role of reality, she

acknowledged having been "a philosophy major" in her undergraduate years. Overall, as can be seen in Figure 4, Ellen's initial ontological profile features the coexistence of realist and radical ontological beliefs. However, statements referring to the realist category were not identified for Ellen after the first interview.

In the second interview, Ellen aligned her ontological beliefs with those of von Glasersfeld's radical constructivism (100% of text units coded in the radical category). After the first term in the M.Ed. program, when she was introduced to the different versions of constructivist epistemologies, Ellen strongly subscribed to von Glasersfeld's radical constructivism as she specifically referred to his way of describing reality in the following:

> We read a bunch of different articles on constructivism. The one that I most liked was the reasoning and argument of von Glasersfeld's constructivism. I am not sure what the category for that is, but he talked about people's knowledge of reality and everybody constructs their individual reality based on acceptance of their social community, also with an influence of social community. But I don't think he was a social constructivist purely. I think he also talked about the individual's being able to be different from what is necessarily just a social construct. I agree with him. (Ellen, interview 2)

When she talked about the role of reality, she replicated von Glasersfeld's argument word for word, including that "there is a reality that exists independently, but nobody has access to it." In addition, she stated that "our theory is the most viable explanation and it fits for our knowledge of our world right now" (Ellen, interview 2). From her standpoint of "perspectivism", Ellen continued to insist that "there is no unmediated access to the real world; therefore, if everyone has their own perspective and everybody constructs their own knowledge, then everybody is not seeing the same thing." Ellen believed that criteria for evaluating our theories should offer a "best fit." That is, "whatever best fits our understanding of the way things work, whatever best fits with the information [we receive] is the best scientific theory" (Ellen, interview 3).

Following the third interview, Ellen's ontological belief profile was 53% radical and 47% idealist. The radical component of Ellen's profile was retained as the largest component in her ontological profile from the second interview on. After the third interview, Ellen revealed a new component to her ontological profile, statements relating to idealist ontological beliefs, as she endorsed the assumption that our perceptions and other representations of the world constitute that reality. In supporting this idealist position, Ellen contended, "just like some parts of the movie, the Matrix," our empirical world could be construction of "these groups of minds" (Ellen, interview 3).

By the end of the fourth interview, Ellen's profile showed the coexistence of radical and idealist ontological beliefs (57% radical and 43% idealist). That is, on the one hand, she took a radical ontological stand when she talked about "no unmediated access to the world, no way to directly access reality," and evaluating and validating a theory based on its' viability. On the other hand, she took an idealist stand when she viewed reality as being "constituted by our perceptions and other sorts of representations" and multiple interpretations or constructions of reality depending on different cultural groups. During the member check following this interview, Ellen acknowledged, "there has been an evolution" in terms of her ontological beliefs, which has been caused by "readings in class." Whether she achieved consciousness with respect to her profile and was able to recognize the implications of each component will be discussed after reviewing her epistemological profile in the following section.

Ellen's Epistemology Profile

Ellen's epistemological profiles showed more variation than her profile for ontological beliefs. After the first interview, Ellen's epistemological profile was 51% Piagetian, 32% Fallibilism, and 17% Relativism. As was the case for other interviewees, Ellen's epistemology is

to some extent related to her ontology (see Kwak, 2001). Aligned with the realist ontological beliefs represented in her first interview, Ellen had the Piagetian position as the largest component of her epistemology profile in the first interview. According to Ellen, this view entailed, "there is a world that someway constrains our creativity or our theories or knowledge" (Ellen, interview 1).

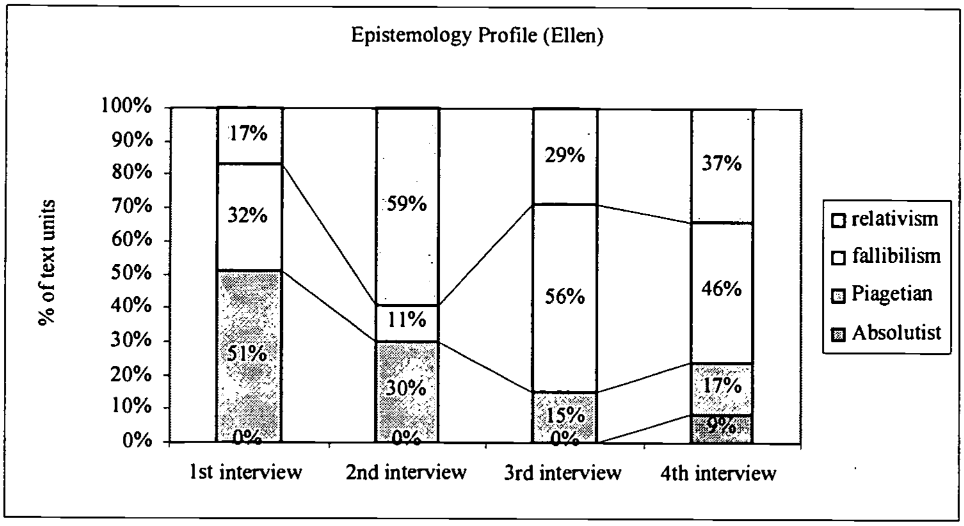

Figure 5: Ellen's epistemological belief profile

Ellen's Piagetian epistemological component--scientific realism in Ernest (1995) terminology-- showed a gradual decrease, but was maintained throughout all interviews: 30% in the second, 15% in the third, and 17% in the fourth interview. Some typical statements placed in the Piagetian category for Ellen included: "I don't think that our knowledge of the world is passive thinking… we are constructing that knowledge" (Ellen, interview 2). Ellen assumed "an inaccessible world" in which humans are striving to reach a viable explanation or interpretation. During the knowledge construction process, "nature might constrain what we reasonably can believe about it" in that "some theories or concepts are ruled out by our evidence or experience

but nature does not uniquely and unequivocally determine" (Phillips, 1997b, p. 170) what we can construct about it. As Ellen put it, "our theories try to be consistent with what we know as reality or what we perceive as reality" and "we judge whether a theory is valid or invalid based on how well it supports the evidence of what we know of the world" (Ellen, interview 3 & 4).

Ellen epistemological profile also contained Fallibilist beliefs in the first interview as she acknowledged the vulnerability of scientific theories to new evidence or interpretation. In accordance with her realist ontological beliefs from the first interview, she stated that we sometimes "totally misinterpret what the scheme of reality is" [and therefore] "all theories are in principle revisable as proven in Newton's physics or probably even in the Big Bang theory" (Ellen, interview 1).

From the second interview on, Ellen subscribed to von Glasersfeld's Radical constructivism. She assumed, "everybody not only constructs his or her individual reality," but also "the individual is able to be different from what is necessarily just a social construct [what is accepted by their social community]." Ellen strongly emphasized, on the one hand, an individual's active, subjective construction of knowledge where "the knower must infer what he or she was hoping to know" and, as a group of individuals, has revolutionized theories throughout history (Ellen, interview 2). On the other hand, she stated that, "whatever theory that best fits with our understanding of the way things work or the evidence of what we know of the world is the best scientific theory" (Ellen, interview 3). That is, Ellen viewed the validity of a knowledge claim as found in its viability or its non-contradictory fit with what one already knows (von Glasersfeld, 1995). This Fallibilist category was the largest component in her third (56% of text units) and fourth interviews (46% of text units):

> I agree that scientific theories are fallible and liable to refutation. I am thinking of my science, geologic history, how that changes over time. Like the ideas of when

> life began changes over time. I would agree with that and, I think, most scientists would agree with B, that our knowledge is provisional or is always open to confirmation, elaboration, revision or change. (Ellen, interview 4)

Another feature of Ellen's epistemological profile is that it contained a relativist component from the first interview on. This relativist component was aligned with her initial radical ontological position. That is, she denied any direct or unmediated access to an external reality. From the second interview on, when she endorsed von Glasersfeld's radical constructivist ontological and epistemological assumptions, the relativist component remained as one of the largest components in Ellen's epistemological profile: 59% in the second interview, 29% in the third, and 37% in the fourth. Ellen contended that society not only creates reality but also "creates scientific theory" by validating and accepting "people's knowledge of reality" (Ellen, interview 1 & 2). When asked to select the forced-choice item consistent with her epistemological beliefs, she consistently chose the relativist option throughout all interviews.

An assumption implicit in Ellen's approach to truthfulness in science is that each individual constructs scientific knowledge that should "corresponds with the accepted version of the world and how the scientific community has agreed to explain something" (Ellen, interview 4). In other words, although "there is no real reality" that can validate one individual's construction over that of another, individuals should construct their own knowledge "corresponding to how the scientific community has agreed to explain something or corresponding with the accepted version of the world" (Ellen, interview 4). Moreover, to be accepted by the community to which they belong, each individual should be "able to explain that theory in a similar language" (Ellen, interview 4). During the member check, Ellen continued to be fascinated by ideas advocated by von Glasersfeld, especially his emphasis on the individual's reality followed by his or her knowledge construction.

In sum, the proportion of text units in the Piagetian category gradually decreased for Ellen's epistemological profile and was replaced by text units representing Fallibilism and Relativist components. This change in Ellen's epistemological profile fit with her ontological belief shift from realist to radical and idealist. That is, as she displaced the notion of an independent existence of the external world with no direct access to reality (i.e., von Glasersfeld's ideas) and, furthermore, multiple realities constructed by people "in a different epistemic community, her epistemological profile shifted from Piagetian to relativist.

One important issue regarding changes in Ellen's ontological and epistemological profiles is how she could transfer her ontological and epistemological beliefs to her views of science teaching and learning. That is, whether or not she recognized that changes in her ontological beliefs and epistemological commitments were impacting her views of science teaching and learning. This issue is discussed in the explainer section that follows her CSTL profile immediately below.

Ellen's CSTL

After the first interview, Ellen's CSTL profile was determined to be 50% traditional and 50% individual. The traditional component of Ellen's profile initially reflected her beliefs about the nature of teaching based on her prior experiences as a student, where she "was a good student who did what she was supposed to" (Ellen, interview 1). Ellen's self image as a teacher that she brought to the M.Ed. program was constructed based on her prior experiences as a student, "assuming that her students will possess learning styles, aptitudes, interests, and problems similar to her own" (Kagan, 1990, p. 145). Having observed both positive and negative teaching models, Ellen's initial CSTL was aligned with her traditional views, where "teaching is

transferring knowledge or skills or concepts from one person or thing to another or to yourself [and] learning is receiving the same things, information, and concepts" (Ellen, interview 1).

As a preservice teacher, she perceived "what will be expected of me as a teacher is to steer or funnel the students towards accepted scientific interpretation or solution," whereas students "will learn it if they are paying attention" (Ellen, interview 1). However, it was rare to locate this traditional component in Ellen's profile from the second interview, where she contended that it is possible "to lecture or introduce ideas from an external authority without pressing to accept that authority, if you choose not to" (Ellen, interview 2). She went on to say that, as a teacher, "if I am going to introduce another position [accepted scientific interpretation or solution], I better have a good way to justify or explain it."

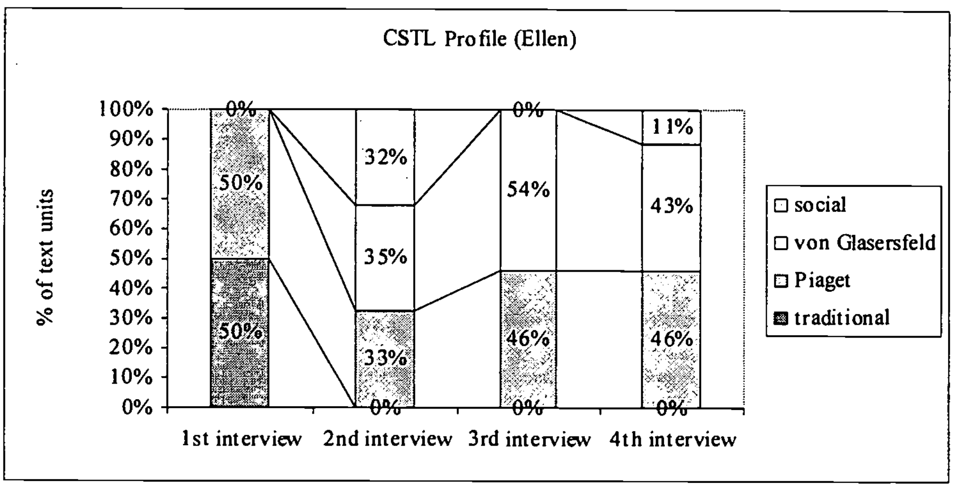

Figure 6: Ellen's CSTL profile

In her first CSTL interview, Ellen aligned her views of teaching with ideas like those of individual constructivism. According to Ellen, teachers should compare the students' and the accepted science points of view for the learner in the following:

> Because of their [teachers'] duty, I think I believe B, but the sentence ['the teacher must not evaluate the students' contributions...'] I think that I couldn't do that. I think I would say, "Oh that's a very good idea. How about blah, blah, blah" or I would definitely guide the situation toward the expected interpretation, standard interpretation, or whatever we're trying to learn. (Ellen, interview 1)

Ellen stated that teaching science involved socializing students into particular ways of viewing the world. This Piagetian component in Ellen's CSTL profile remained the largest or second largest component throughout all remaining interviews: 33% in the second interview, 46% in the third, and 46% in the fourth interview.

According to Ellen, one of her main rationales for science teaching was to have "students understand a best approximation of accepted scientific ideas" and "it is the teacher's responsibility to expose students to the accepted scientific interpretation" (Ellen, interview 2). She went on to say, "the method of doing that can be constructivist and doesn't necessarily have to be through traditional teaching." "In order for children to really understand what's going on," Ellen stated, students need to "go through some sort of conceptual change.... misconceptions need to be restructured" (Ellen, interview 2). Although Ellen was initially unsure of "whether she can be that kind of teacher or not," she was inspired by the learning reported in Sister Gertrude Hennessey's (1991; 1992) science classroom stating that "[Sister Gertrude] was able to introduce the interpretations of the scientific community without necessarily imposing those perspectives on her students as an authority" (Ellen, interview 2).

Ellen's CSTL profile changed to 33% individual, 35% radical and 32% social after the second interview, and to 46% individual and 54% radical after the third interview, when the social component disappeared all together. In the second interview, Ellen was fascinated by social constructivists' ideas such as the notion that students develop common perspectives with regard to objects and events in the world through communicating among themselves (Prawat,

1996). However, Ellen's view of herself as a teacher always reverted to enculturating students into the conventions of the science community. According to Ellen, "students' creating their own knowledge is not necessarily practical in the schools" (Ellen, interview 3). Whenever asked to choose one of the preferences that most aligned with the ways she thought about science teaching and learning, she chose an individual constructivist perspective to "compromise what she was supposed to be doing as a teacher in classrooms."

> I think practically, the kind of teacher that I probably would be is most likely E [the individual constructivist option]. I like B [the social constructivist option] but it seems like it might take too much time... sort of like you would be unable to do it as a teacher with fifteen learning objectives that you are required to go over throughout the year. (Ellen, interview 4)

Ellen also stated that "students' own interpretations of ideas in their own heads, or their own ideas constructed for themselves, may not be consistent with what the teacher intended for them to learn" (Ellen, interview 4). Thus, she emphasized, "teaching must involve a process of regular feedback and checking [with the students] to identify the reasoning students are using." In effect, she would check with her students to understand how they are justifying and explaining their interpretations. In sum, Ellen perceived her role as "teach[ing] an agreed-upon, accepted scientific knowledge" (Ellen, interview 3). Ellen wanted to deliberately encourage "the scientifically acceptable viewpoint" in that "it was to the student's benefits to know the established beliefs and knowledge that a scientific community has agreed upon" (Ellen, interview 4).

After the fourth interview, Ellen's CSTL profile changed to 46% individual, 43% radical and 11% social. The social component first emerged in the second interview (32% of all text units) when Ellen stated that teachers "have to guide institution of scientific activities in the classroom" (Ellen, interview 2). To achieve this goal, she, as a teacher representing the scientific

community, would model “how to think scientifically, to analyze, to act, and to reflect” according to the rules of canonical science (Ellen, interview 2). However, she was unsure “if she [could] implement scientific methods and scientific traditions in her classroom” and, in turn, had to compromise her ideal approaches to teaching and learning because of external time constraints and the amount of content she felt required to be covered.

On the other hand, Ellen always maintained an emphasis on subjectivity. She continued to be fascinated by “individual’s being able to be different from what is necessarily just a social construct” (Ellen, interview 2). With her emphasis on subjectivity, Ellen described learning as a highly individualistic process whereby an individual constructs knowledge in the process of making sense of his or her experiences. This fits well with von Glasersfeld’s notion of radical constructivism and, as can be seen in Figure 6, Ellen maintained this radical constructivist perspective as follows: 35% in the second interview, 54% in the third, and 43% in the fourth interview. However, “everybody constructs their individual reality based on the acceptance of their social community… with the influence of social community” (Ellen, interview 2). That is, in the process of an individual student’s constructing knowledge, Ellen acknowledged, "social communities" as well as "our prior understanding" act as constraints (Ellen, interview 4). Accordingly, Ellen believed that her role was to “have students learn what the current society regards as having the greatest viability” (Ellen, interview 4) and that a teacher must be concerned with what goes on in the student's head if she hopes to change the student’s conceptual structures. Moreover, Ellen stated, “as a subjective sense making activity, learning goes through some sort of conceptual change where misconceptions need to be restructured in order, for children, to really understand what's going on” (Ellen, interview 4). A consistent rationale for

Ellen's science teaching was for her to lead students towards conventional science ideas, because that is "what the current society regards as having the greatest viability" (Ellen, interview 4).

In sum, Ellen "rejected traditional pedagogy, which would be a traditional lecture format and traditional test" after having "been exposed to different ideas of how to teach and the responsibilities of teaching" (Ellen, interview 4). She was greatly influenced by the epistemological and pedagogical perspectives proposed in von Glasersfeld's radical constructivism. She "incorporated the ideas about children as individuals with different perspectives as valid" and she speculated that she would "address different learning styles or different strengths of the individuals and help them come about making links between their conceptions and the science view" (Ellen, interview 4). When talking about her goals for teaching science, Ellen's focus was on students' knowing "the expected interpretation, standard interpretation" (Ellen, interview 1), "thinking scientifically using a scientific method to explain how the world works" (Ellen, interview 2), and "having an appreciation for science" (Ellen, interview 4).

Ellen's explanations for change

Asked to provide the most influential factors in helping her change her beliefs about teaching and learning, Ellen indicated that "the structured coursework" of the MSAT M.Ed. program was the most influential factor. This coursework helped her see "what the alternatives were in terms of different learning theories" (Ellen, interview 4). Ellen stated that she came into the program "with a certain perspective and it has been enlightened and enlarged, but not changed dramatically." From the beginning of the program, she argued, she could "teach right now in a lecture format. You can always get in front and you can lecture. That's not the problem.

The problem is trying to make it engaging so that kids will actually learn something" (Ellen, interview 4).

What she wanted to know from the teacher education program was "how we might implement something else" and "alternative points of view, particularly in terms of talking about integration and constructivism and active hands-on learning." Ellen also stated, "I really don't think the M.Ed. program has influenced my beliefs about teaching and learning very much." While the M.Ed. program helped her to "put some vocabularies to it, like constructivism, but in general my ideas about what students should get from a science classroom and what a teacher should be doing to facilitate haven't really changed." The program, she argued, may have helped her put her ideas in "a little bit more concrete ways because of readings that I did and learning what other people believe, whether it's my peers or Piaget or even the self-reflections that we have been asked to write" (Ellen, interview 4).

Additional factors that influenced her CSTL included "group discussions with her peers where problems and ideas were discussed, and actually being in schools talking to teachers, and teaching myself through field experiences" where she could observe "a bunch of different teachers." She also suggested, "the most practical way to learn as a teacher is to combine coursework with teaching or observing experiences." In this way she thought she could apply theory to practice. In addition, when asked to reflect on any significant changes in herself as a teacher throughout the M.Ed. program, Ellen commented that she "incorporated a lot of different ideas of how to teach and my responsibilities of teaching, and learned how to address different learning styles."

Asked to explain the belief changes represented in her profiles, she commented, "there has been an evolution" in that she moved away from the "traditional pedagogical perspective and from the realist ontological perspective" and toward von Glasersfeld's perspective.

Regarding the extent to which she was conscious of the relationship between her ontological or epistemological beliefs and CSTL, she stated, "there is a link to that [how ontological perspective might influence on her pedagogical perspective]." Ellen's alignment of her ontological and epistemological beliefs with those informed by von Glasersfeld's radical constructivism mapped onto her preferred "pedagogies based on a radical constructivist perspective." Accordingly, she identified "knowledge as a subjective sense-making activity for learners. When asked to comment on how her strong endorsement of von Glasersfeld's perspectives would influence her teaching, Ellen said, "hopefully that goes into my ideas about children as individuals with different perspectives and a lot of their opinions are valid" (Ellen, interview 4).

Ellen wanted students to learn accepted scientific knowledge because, she thought, that knowledge was what the current society regarded as having the greatest viability at this particular time. Although Ellen was aware of "what the idealist and relativist would say" in terms of the role of reality in knowledge construction, she wanted to deliberately encourage students "to learn the theoretical ideas and conventions of the science community" in her science classroom. Knowing the "established beliefs and knowledge that a scientific community has agreed upon," Ellen contended, "her students, who are members of this Western scientific community, would benefit" (Ellen, interview 4). It is important to note that Ellen was also aware that each student constructs reality, as well as scientific knowledge, in different ways depending on his or her everyday culture or experiences. However, as a science teacher in a Western community, Ellen

would give preference to the view adopted by the science community so her students' could function and survive in their Western scientific traditions.

Regarding her overall CSTL profile, Ellen maintained the Piagetian as the largest component, and von Glasersfeld's radical constructivist component from the second interview on. It was just prior to this interview when she was introduced to various versions of constructivism in the M.Ed. program. Ellen's emphasis on individualism in knowledge construction as well as science learning led her to recognize that students would "interpret the lecture to fit his or her own knowledge framework. Therefore, what they learn might not necessarily be the information that the teacher is imparting to them" (Ellen, interview 2). Ellen also showed a gradual decrease in the social component of her CSTL profile as she was frustrated by the amount of lecturing she observed and content she felt required to cover during her field experiences:

> I will be constrained by the fact that I will have thirty kids per period, one hundred and fifty kids per day with a course of study that covers multitude of topics. It's also my responsibility to prepare these children for [state mandated] proficiency tests or to get to them more information than just scientific methods. Even though how to think in a scientific fashion or how to be reflective is important to me, and that's part of what science is about, obviously I have to teach more than that to my students. I have to have content that goes beyond pure constructivist's discovery methods or whatever. (Ellen, interview 4)

In conclusion, other than the disappearance of traditional pedagogical beliefs, Ellen maintained a consistent CSTL profile without showing any radical change.

Conclusions

The two case studies presented here indicate that there was change in the sub-components of the educational constructivist profiles for these preservice teachers. This study demonstrated that the notion of a constructivist profile containing ontological beliefs, epistemological

commitments, and pedagogical beliefs could be aligned with conceptions of science teaching and learning. It also demonstrated implications that changes in components for an educational constructivist profile have for a preservice teacher's view of themselves as teacher. However, changes in ontological and epistemological beliefs are not easy, nor are they easily internalized (Chinn & Brewer, 1993; Chi, 1992). While the possibility that change can occur in two preservice teacher's profiles was documented, only five of 16 participants involved in the larger study showed any change. On the positive side, when change did occur, these changes were attributed to the coursework associated within this preservice teacher education program. Teaching about constructivist philosophies, as this program did, helped some preservice teachers develop conceptions of teaching and learning that were well grounded philosophically.

The overall conclusion drawn from this research is that preservice teachers can develop 'constructivist' notions of teaching that are consistent with and founded upon philosophical principles. For teacher educators attempting to change preservice teachers views on teaching, preservice teacher education programs should challenge their student's ontological beliefs and epistemological commitments if they expect to see changes in how science is taught and learned. For researchers, this study offers insights into the reasons that preservice students give for changes in their thinking about learning to teach.

Implications for Further Research

Constructivist-oriented preservice teacher education programs can help preservice teachers change their constructivist profiles when those programs are firmly grounded in epistemology. Continued examination of changes in preservice teachers' beliefs towards educational constructivism, or any other version of constructivism, would provide important

information about the extent to which these views can be applied in their science classrooms. Therefore, further research is needed to know if (and how) the changes observed in this study are effected by the contexts and dynamic interactions that occur when these students are no longer exposed to university faculty. Questions that arise for us are: how will these participants' profiles change as a result of their student teaching, and when they enter the first few years of teaching? That is, longitudinal studies of profile change should be conducted. To address this question, as Richardson (1996) contends, we propose further research that "moves beyond descriptions of preservice teachers' beliefs and conceptions and toward the observation of teaches' actions in the classroom" (p. 114).

Finally, as noted earlier, the participants involved in this study attributed the most influential factor in developing a constructivist perspective on teaching and learning to one or two faculty members of the MSAT program. In other words, above anything else, these exemplary teacher educators left a deep impact on preservice teachers' formation of their beliefs towards a constructivist learning and teaching framework. Accordingly, further research on the personal and professional characteristics of exemplary science teacher educators is needed.

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SHARING OUR STRATEGIES: A NEW ROLE FOR SCIENCE TEACHERS

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Urban science education continues to be plagued by the decreasing number of female and minority students enrolling and completing advanced math and science programs. As the nation's economic base shifts increasingly toward science and technology, students' lack of achievement and participation in science combined with a negative attitude toward science, generates growing concern.

Science and mathematics achievement scores, particularly among females and minority students, continue to be one of the most visible and troubling factors in the nation's educational efforts. Demographic projections show the traditional pool that supplies scientific workers is shrinking; there is a need to encourage participation in science and technology among the non-traditional pool the majority of whom comprise women and minorities, mainly blacks and Hispanics from at-risk populations congregated in the urban setting.

Contemporary research indicates that gender, cultural and psychosocial barriers, combined with inadequate pedagogical and curricular strategies, are the major contributing factors to low participation, interest and achievement in science (Bradley 1997; Greenfield 1996; Hammer 1996; Klein et al. 1997; Lee and Burkan 1996; Parson 1997). According to Zeichner (1995), the literature suggests that the key elements to enable all students to achieve high standards are: high expectations for all students; cultural congruence in instruction; teacher knowledge and respect for cultural traditions; and teaching strategies that promote meaningful participation.

Weiss (1993) gathered data from approximately 6000 teachers of science and math in grades 1-12 about their beliefs and practices. Her findings pinpoint the two types of factors which affect science teaching and learning, which are also good descriptors of science education in the urban school settings, i.e. socio-economic and pedagogical factors.

Although Weiss' study examined the U.S. in its entirety, the findings are clearly exemplified in the New York City urban teaching environment. In New York City, socioeconomic factors appear to be a major contributor to poor performance and participation. Teachers are, therefore faced with the challenge of applying adequate pedagogy in a situation which is socio-economically deprived. As teacher educators we realize that we have no direct control over the socioeconomic factors, however we can influence the pedagogical and must therefore prepare our students to teach using strategies that improve performance and participation in spite of the socioeconomic conditions.

It is within this context that the author began a specialized teacher education program for selected New York City science and mathematics teachers. As part of this program participants have developed, implemented and evaluated strategies for increasing interest and participation in science and mathematics. However on completion of the program there did not exist a forum for continued sharing of these successful strategies. To celebrate the tenth year of our successful Math, Science and Technology Project (MSTEP) a summer conference entitled "Sharing Our Success" on Urban Science Teaching was held in May 2000. The conference provided a forum for urban 7-12th grade math and science teachers, school district personnel and science educators to meet and discuss successful strategies for increasing interest and participation in science and math.

This conference addressed the fourth of Zeichner's elements:" teaching strategies that will promote meaningful participation." As part of the conference teachers, were able to build on professional experiences, and explore policy and practice. Workshops and discussion focused on the new math and science standards; teacher directed action research, strategies for dealing with diversity in the classroom and the implementation of teacher-designed curriculum units. Through their articulation of their professional development, the teachers demonstrated their new role: that of master science/teacher researcher.

It is anticipated that this model can be replicated in urban settings nationally.

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SISTERS IN SCIENCE: USING SPORTS AS A VEHICLE FOR SCIENCE LEARNING

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The previous decade has witnessed many voices calling for reform in the teaching of science and mathematics. The federal government identified six National Education Goals that boasted the United States would be first in the world in science and mathematics by the year 2000 (Culotta, 1990; Vinovski, 1996); and it is presently launching a series of exams in reading and mathematics to improve student achievement and increase the status of American students in an ever-increasing global marketplace (Baker, 1997). Furthermore, policymakers, scientists and mathematicians have focused on change to develop the scientific and mathematical knowledge that will produce a healthy economy and maintain a meaningful democracy (Tate, 1994). Reform, however, does not occur overnight. Systemic reform must remain on the national agenda if we as a nation hope to attain the goals posed by the federal government and such professional organizations as the National Council of Teachers of Mathematics and the American Association for the Advancement of Science.

The conditions of many urban schools and the communities to which they belong are appalling (Apple, 1992; Kozol, 1991). Lifelong learning in science, mathematics and technology is impossible to realize when many urban students have no access to the Internet and fewer textbooks, manipulatives and science equipment than suburban students. In particular, minority students (i.e., African-Americans, Latinos and women) and students from low socioeconomic backgrounds confront great structural challenges in choosing and performing well in science,

mathematics and technology related fields (Hammrich, 1997; Hanson, 1996; Oakes, 1990). Innovative programs must provide access to the newest and most advanced tools in science, mathematics and technology. Furthermore, awareness of cultural differences, including learning style, need to be an integral part of the format, organization and content of an effective program. A current view of how individuals receive and process information proposed several (rather than just one) independent forms of information processing, including logical-mathematics, linguistic, musical, spatial, bodily kinesthetic, interpersonal and intrapersonal (Gardner, 1993). Because individuals may differ in their specific profile of "intelligences," education needs to be diverse in its offerings, both in terms of content and format of instruction, in order to be effective (Nieto, 1996).

The AAUW (1998) publication "Gender Gap: Where School Still Fail Our Children" suggests that "Sports participation in general is linked not just to higher academic achievement but also to better physical and mental health and greater leadership capacity. . . Like classroom interactions, sports can either challenge or reinforce stereotypes about girls' and boys roles." (p. 74). and ". . . Unique capacity of school sports to prompt students and adults to question their own assumptions about gender (p.77). Other research supports the positive relationship that exists between participation in extracurricular activities and school success (Lamborn et al.).

The Sisters in Sport Science (SISS) program supports and furthers this vision by providing mathematical and scientific concepts through the vehicle of sports. In doing so, the program is successfully reaching students in a variety of ways and strengthening the education of students in science and mathematics by creating an unique and diverse pedagogical atmosphere.

Girls and minority youth in the late elementary through middle school years tend to struggle with self-esteem, physical fitness, skill development, goal setting, and problem solving.

Sports are one ideal mechanism to reach girls and minority youth during these uncertain years in which they explore their self-identities. Research links physical activity for girls to higher self-esteem, positive body image, and lifelong health (AAUW, 1998, p. 20) and "... involvement in activities valued by school (athletics and the arts) leads to higher self-esteem, positive attitudes toward school, and less self-destructive behavior."(AAUW, 1998, p.77). By using sports as a vehicle for learning scientific principles, the SISS program is responding to the national call for creating innovative programs that provide access to the latest strategies in promoting science literacy.

Program Description

Rationale

SISS addresses the need for urban girls to gain equitable access to science and mathematics education by using sports as a vehicle for learning. Specifically this need is based on the rising public concern over the equity gap in science and mathematics; recognition of the significant impact intervention programs targeting urban girls have on school success; and the call for systemic educational reforms that recognize the limits minority girls face in post secondary education and employment opportunities.

SISS addresses the diversity inherent in learning by using sports as the context through which scientific and mathematical principles can be explored. Through the vehicle of sports not only are girls learning the underlying principles of science and mathematics embedded in the mechanics of performing a sport; but also, they are learning the scientific principles in an atmosphere that embraces the psycho-social-emotional connection to learning. For instance, each day girls learn how to ride a bike, throw a ball, and/or jump rope. They learn these activities in

an environment that is non-competitive and non-threatening academically. What they are not aware of is the scientific and mathematical principles laden in performing these activities. In the classroom girls learn these scientific and mathematical principles in a context which is foreign to their everyday experiences. They learn about the trajectory of a golf ball without connecting this principle with the actual of practice of hitting a golf ball. What is unique about the concept of SISS is that the academic and the everyday experiences of girls are bridged. To this end, the teaching and learning process embraces not only the academic principles of learning but captures the psycho-social-emotion process of learning. In doing so the context of learning science and mathematics is enriched for the girls.

While programs that address the equitable achievement for all students in science and mathematics are not new, using sports as a vehicle through which science and mathematics interest and achievement can be attained is unique. This approach bridges the application of concepts embedded in science and mathematics to the mechanics of performing a sport. Sports provide a unique and innovative approach to reaching girls in a friendly atmosphere while learning concepts usually too abstract for them to grasp due to their limited experience and exposure. By using sports as a vehicle for learning scientific and mathematical principles, the SISS program is responding to the national call for creating innovative programs that provide access to the latest strategies in promoting science literacy.

Goals and Objectives

The overall goal of the proposed project is to design, implement, evaluate, and disseminate a field-based program aimed at fostering the resilience of minority girls, grades 6^{th} – 8^{th}, in science and mathematics through the vehicle of sports. The project builds upon the two-

year intervention of the *Sisters in Science* program and provides second level of intervention for a sustained longitudinal look at how girls are achieving in math and science. The project builds upon the existing SEM curriculum through specific activities and learning methods shown to increase minority girls' interest and achievement in SEM through the vehicle of sports. The following objectives are being pursued:

- To increase science and mathematics achievement of minority middle school girls through the vehicle of sport.
- To increase the number of effective teachers and coaches who will co-facilitate sports as an avenue for science and mathematics learning.
- To enhance the self identities of minority girls in the areas of self esteem, physical fitness, skill development, goal setting, and problem solving through the vehicle of sport and science and mathematics.
- To increase families and caregivers knowledge of sports as an effective way to foster science and mathematics achievement.
- To increase minority girls careers awareness of science, mathematics and sport related fields.

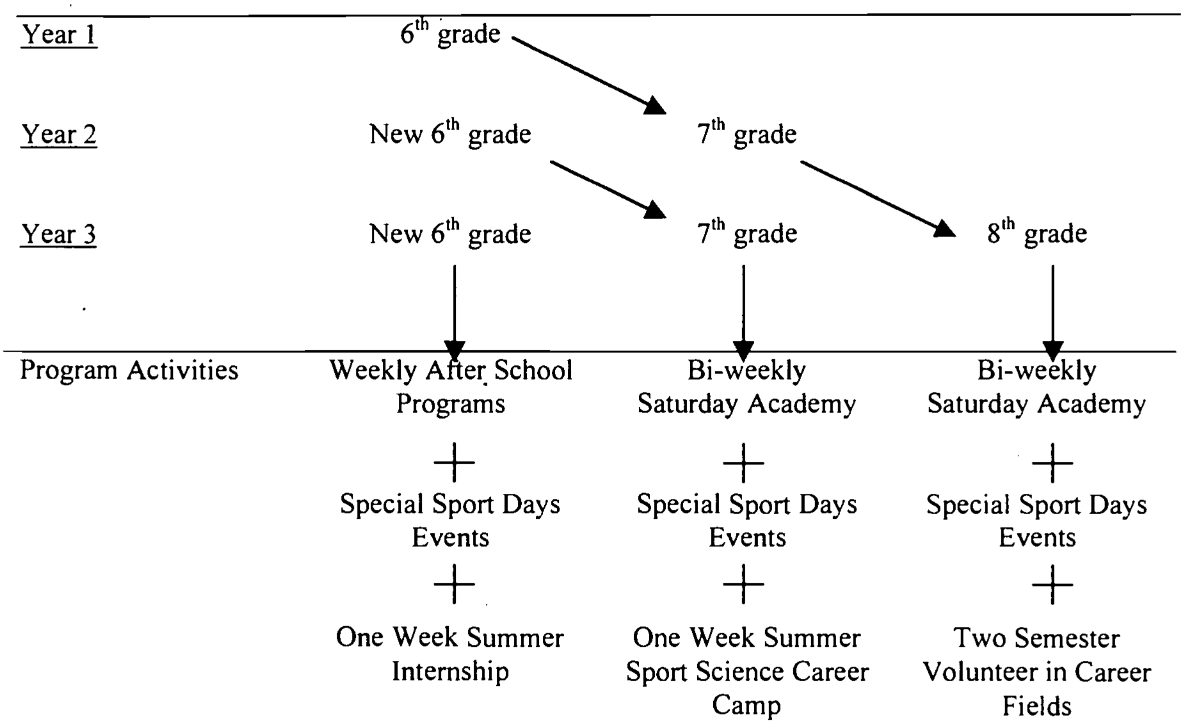
Program Components

The proposed project is designed as a three-year intervention involving middle school minority girls from six middle schools over a three-year period (see Figure 1). The focus is on providing a longitudinal intervention at the middles school level that expands on the efforts of the *Sisters in Science* program, which targets the elementary level. This three-year intervention is devoted to developing, implementing, and expanding program activities that have been piloted in the *Sisters in Science* program and longitudinally tracking girls through the second level of

intervention. Through the utilization of minority athletes, middle school teachers, university students, as well as summer internships, career camps, academic internships, and family involvement the project will have a direct impact on girls, parents, and the SEM curriculum by focusing on sports as a vehicle for science and mathematics learning. All sport science activities are matched to the Philadelphia middle school science and mathematics standards. One of the outcomes of the program will be the expansion of such concepts as force, motion, geometry, and mechanics. By enhancing the capacity to promote science and mathematics literacy through the utilization of sports, the project supplements other systemic initiatives at Temple University and the School District (Sisters In Science, Daughters with Disabilities, Collaboration for the Excellence in Teacher Preparation, Alliance for Minority Participation in Science and Mathematics, and the Urban Systemic Initiative). The project will rely heavily on incorporating existing sports activities developed by the Black Women in Sport Foundation and the sport science activities developed in the Sisters in Science program.

Figure 1.

Three Year Intervention Model



The project builds upon the existing SEM curriculum through specific activities and learning methods shown to increase minority girls' interest and achievement in SEM through the vehicle of sports. The SISS project includes the development of a supplemental science and mathematics curriculum through the utilization of sports. The curriculum enhancement is standards based and has an equity focus. Each activity features a specific sport and the science and mathematics utilized in performing the sport and features an athlete from the sport and a scientist or mathematician. The entire three-year supplemental curriculum includes 10 sports, 40 science and mathematics standards driven activities that feature a sport as the mechanism through which the science and mathematics is learned. The ten sports featured in the curriculum program include: (a). five team sports – volleyball, basketball, soccer, hockey, and softball; and (b) five individual sports - fencing, golf, tennis, track (running), track (throwing). The project

will achieve the goals and objectives through 5 components: (a) after school programs; (b) Saturday academies, (c) special sport day events; (d) academic and summer internships; and (e) career connections.

In Year 1, the first level of intervention will include the targeted 180 sixth grade girls from the six schools. The following sports are targeted: fencing, tennis, golf, and basketball. The girls are participating in the following activities during year one.

After school programs.

The after school programs are conducted at each of the six school sights one day a week for 20 weeks from 3:00 PM to 5:00 PM: Ten weeks during the fall and ten weeks during the spring. One graduate student and one teacher from each school act as co-facilitators of the curriculum during the after school sessions. Undergraduate education students and minority athletes support the co-facilitators. Since there are four sports that are featured each sport lasts five weeks. This provides ample time for the girls to grasp both the sport and the science and mathematics principles applied in performing the sport. The after school program has the minority girls participate for one hour on sport mechanics and one hour on the science and mathematics principles in performing the sport.

Special sport day events.

There are four special sport day events. Each sport day will are conducted on a Saturday following the 5 week rotation of the sport conducted in the after school program. Families join their daughters in participating in the sport. The girls prepare a short presentation of the science and mathematics principles applied in performing the sport. Families are given a *Sport Science Poster* outlining the sport and the corresponding science and mathematics principles.

Summer Internships.

On a competitive basis 20 percent (45-50) of the minority girls are awarded summer internships. These internships are for one week in length and are used to shadow someone in a career path that interests her. Such possible internships include: sport therapy, exercise physiology, coaching, biomechanical engineer, exercise scientist, althetic trainer. The girls receive service credit from their school for successfully participating in the internships. Girls are expected to keep a reflective journal of their experience and write a report.

In Year 2, the second level of intervention will include the targeted 180 sixth grade girls in Year 1 now seventh grade girls at the six schools. Also in Year 2 a new set of targeted 180 sixth grade girls will start the first level of intervention mentioned above. The following sports will be targeted in the second level of intervention at the seventh grade: volleyball, soccer, track (running). The girls will participate in the following activities during Year 2.

Saturday academy programs.

The Saturday academy programs will be conducted at Temple University bi-weekly for 20 weeks from 10:00 AM to 2:00 PM. Ten weeks during the fall and ten weeks during the spring. Two graduate students and one teacher from each school will act as co-facilitators of the curriculum during the Saturday academy sessions. Undergraduate education students and minority athletes will support the co-facilitators. Since there are three sports that will be featured each sport will last approximately 5-8 weeks. This will provide ample time for the girls to grasp both the sport and the science and mathematics principles applied in performing the sport. The Saturday academy program will have the minority girls participate for one hour on sport mechanics and three hours on the science and mathematics principles in performing the sport. The girls will spend more and more time on the science and mathematics during Year 2 of the intervention. Another highlight will be the inclusion of technology in simulating the science of

the sport through computer simulations. We will partner with the College of Technology and Engineering at Temple University to help with the inclusion of technology. We have successfully worked jointly with them during the *Sisters in Science* program.

Special sport day events.

There will be three special sport day events. Each sport day will be conducted on a Saturday following the 5-8 week rotation of the sport conducted in the Saturday academy program. Families will join their daughters in participating in the sport. The students will prepare a short presentation of the science and mathematics principles applied in performing the sport. Families will be given a *Sport Science Poster* outlining the sport and the corresponding science/mathematics principles.

Summer Sport Science Career Camp.

On a competitive basis 20 percent (45-50) of the minority girls will be awarded summer internships to participate in the sport science career camp. The career camp will focus on revisiting the science and mathematics of the sports conducted so far and a more intensive exploration of the career connection. The girls will spend the week conducting extensive research on the science and mathematics behind one of the sports and conducting an experiment that both focuses on a career as well as on a current issue in science and mathematics. (For example in track – running. A topic could be - How has the speed of an athlete changed exponentially over the history of time? Some girls may choose to look at the bio-mechanics embedded in the issue while other girls may pursue the science of technology that could have led to the increase in speed.) The girls will be partnered up electronically with a scientist in the field of her choice. They will conduct an experiment to test their hypothesis. During the last day the girls will present their results. The girls will be partnered up with Temple and LaSalle University

students during the camp to help the girls with their research projects on a daily basis. The girls will receive service credit from their school for successfully participating in the camp.

In Year 3, the third level of intervention will include the targeted 180 sixth grade girls in Year 1 now eighth grade girls at the six schools. Also in Year 3 a new set of targeted 180 sixth grade girls will start the first level of intervention mentioned above and the second level of intervention will entail the Year 2 sixth grade girls now seventh grade girls. The following sports will be targeted in the third level of intervention at the eighth grade: softball, hockey, track –throwing. The girls will participate in the following activities during Year 3.

Saturday academy programs.

The Saturday academy programs will be conducted at Temple University bi-weekly for 20 weeks from 10:00 AM to 2:00 PM. Ten weeks during the fall and ten weeks during the spring. Two graduate students and one teacher from each school will act as co-facilitators of the curriculum during the Saturday academy sessions. Undergraduate education students and minority athletes will support the co-facilitators. Since there are three sports that will be featured each sport will last approximately 5-8 weeks. This will provide ample time for the students to grasp both the sport and the science and mathematics principles applied in performing the sport. The Saturday academy program will have the minority youth participate for one hour on sport mechanics and three hours on the science and mathematics principles in performing the sport. The girls will spend more and more time on the science and mathematics during Year 3 of the intervention. Another highlight will be the inclusion of technology in simulating the science of the sport through computer simulations.

Special sport day events.

There will be three special sport day events. Each sport day will be conducted on a Saturday following the 5-8 week rotation of the sport conducted in the Saturday academy program. Families will join their daughters in participating in the sport. The students will prepare a short presentation of the science and mathematics principles applied in performing the sport. Families will be given a *Sport Science Poster* outlining the sport and the corresponding science and mathematics principles.

Academic Internships in Career Fields.

On a competitive basis 20 percent (45-50) of the minority girls will be awarded academic internships to participate in year long sport science career projects. The career projects will have the girl's partner up with a person in a field they wish to pursue. The girls will design a research project in consultation with the person in the field. The will visit the person in the field once a month while simultaneously having contact with these individuals on-line. The girls will spend the year designing and conducting their research project. The girls' projects will be showcased at the end of the year at a special Sport Science Career Night presentation. For example, a girl may want to pursue a research project in the area of sports medicine. A topic could include the level of activity pursuant to a injury to the anterior cruciat ligament on the range of movement achieved as a result of different types of corrective surgery or other options available. The girls will receive service credit from their school for successfully participating in the internship.

Program Evaluation

Method

The Sport Science program is a three-year intervention involving 540 middle school minority girls from six middle schools over a three-year period, teachers, college

students, minority athletes, and mentors. The focus is on providing a longitudinal intervention at the middle school level that expands on the efforts of the *Sisters in Science* program, which targets the elementary school. The six middle schools participating in the SISS program are the feeder schools from the *Sisters in Science* schools.

The assessment plan will have two components: one, which is essentially an outcome or impact assessment, and the other an analysis of the processes undertaken before and during program implementation. The former will measure quantifiable results while the latter will provide a qualitative gauge of service delivery.

With regard to the outcome assessment, this will have two parts. First, all 540 youths (or the number who complete the program) that participate in the program will be assessed at the program's end to determine if they acquired the specific knowledge and information that was imparted.

There will also be a quasi-experimental portion to the outcome assessment. Forty youths (out of the 240) will be randomly selected from the targeted schools by Temple to participate in the program. These 40 will constitute the experimental group. The remaining 200 will self select into the program or be chosen by teachers or school officials. Temple will randomly select another 40 (above the 240) to service as the control group. This group of 40 will not receive program services. The random selection of 80 youths should limit the impact of any alternative or intervening variables. Students from both experimental and control groups will, in all probability, be from similar socioeconomic backgrounds, since they will be chosen from the same schools and neighborhoods.

At the end of the program the 80 youths will be assessed and compared with respect to their self-esteem, behavior in school and their academic performance in science and mathematics. Report cards and Stanford Nine scores will be used for behaviors, science and mathematics comparisons. The Student Self-concept Scale will be administered when evaluating the control and experimental groups for changes in self-esteem. The results from both groups will be averaged and formatted in tables. Associations between independent (program activities) and dependent (grades, behaviors and self-esteem) variables will then be deduced and analyzed.

The second component of the evaluation plan will be the process aspect. It will focus on The program work plan and will assess the degree to which benchmarks and timelines were met. Issues such as recruitment parent participation and participant satisfaction will be reviewed. A narrative report, including the results of participant surveys, interviews and focus groups will be composed to give a comprehensive exposure of the program's performance.

Results

Since the SISS program is in its first full year of implementation the results are forthcoming. However, preliminary findings to date show that the girls in the program have increased their interest and achievement in science and mathematics and the relevance of science and math to the sports in which they have participated in so for within the program. For example, of the 20 students who were interviewed during the first Special Event at Temple University's campus, all indicated that they were having fun, were enjoying the program, and were able to cite at least one fact about tennis that they had not known prior to participating in the program. Eighty percent (16 of the 20) of the respondents could remember scientific facts that were learned during the program sessions. For example, respondents mentioned facts about angles, measurements,

reflection, and awareness of careers in science. Seventy percent (14 of the 20) respondents felt that the SISS sessions reinforced the science instruction that they had received in school from their teachers. One hundred percent (20 of the 20) respondents felt that playing tennis was what they liked most about the program. The girls in the program have an increased understanding of science and math learning and see the relevance of science and math to their everyday lives. Informal conversations also show an increase in girls' awareness of careers in science and sports.

Implications

While programs that address the equitable achievement for all students in science and mathematics are not new, using sports as a vehicle through which science and mathematics interest and achievement can be attained is unique. This approach bridges the application of concepts embedded in science and mathematics to the mechanics of performing a sport. Sports provide a unique and innovative approach to reaching students in a friendly atmosphere while learning concepts usually to abstract for them to grasp due to their limited experience and exposure.

Another unique feature of this project is the focus on middle school science and mathematics. It responds to a dearth of attention to this level in public schools and fills a gap in the relevant literature. Middle school students often experience a drop in grades due to lack of organizational skills and difficulty adjusting to the requirements of several teachers. Learning science and mathematics principles through participating in sports will help students through this transition phase and will reduce the chances of "falling through the cracks."

The project is also targeting students who have participated at the elementary school level in *Sisters in Science*. The middle schools chosen are the elementary school feeder schools. This program will allow the students to continue in an intervention program aimed at helping them succeed in science and mathematics. It will also allow the researchers to longitudinally track girls who participated in *Sisters in Science* and then continue to participate in the SISS program creating a second level intervention or double treatment.

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STRATEGIES ENABLING COLLABORATIVE TEACHER TEAMS TO DEVELOP AND IMPLEMENT ASSESSMENT OF STUDENT UNDERSTANDING OF SCIENCE

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This paper shares the findings from three years of Eisenhower funded research which identified conceptual obstacles and enabling strategies for teams of grade 4-12 teachers to conduct collaborative action research by developing and implementing integrated standards-based science and mathematics teaching and assessment plans in their classes. The program provided professional development for 65 teachers in 30 teams of science and mathematics teachers in 10 rural and urban school districts to develop and implement integrated teaching and assessment plans that follow the *National Science Education Standards* (NRC, 1996), the *Principles and Standards for School Mathematics* (NCTM, 2000), and the *Standards of Learning for Virginia Public Schools* (Board of Education Commonwealth of Virginia, 1995). Though the research investigated both teaching and assessment, this paper focuses on assessment.

As teachers change the way they teach to meet new national and state standards, they need to also change the way they plan for teaching and assessment. The purpose of this research was to identify conceptual factors that limit teachers' ability to successfully develop and implement teaching and assessment plans for their students. The main areas for teacher professional development during the summer and implementation year were standards-based, integrated science and mathematics subject matter and pedagogy, and planning for teaching and assessment. Though the science theme varied from year to year, an underlying focus on data analysis and experimental design remained. This paper focuses on the support scaffolding that enabled teachers to successfully create and implement standards-based assessment plans.

This study has implications for K-12 teacher professional development as we seek to help individual teachers and teams of teachers plan for standards-based teaching and assessment. As obstacles are identified and enabling strategies developed, teachers will be better able to plan and teach in ways called for in the state and national standards for science and mathematics.

Theoretical Underpinnings

The study grew out of the recognition of the increasing importance for universities and schools to work together to support the teaching and learning of science and mathematics. It also grew out of the need to help teachers develop a vision of the kind of teaching and assessment called for in the *National Science Education Standards* (NRC, 1996), the *Principles and Standards for School Mathematics* (NCTM, 2000), and *Benchmarks for Science Literacy* (AAAS, 1993), and the need to implement this type of learning and assessment in their classes (Sterling, 1997, 2000; Sterling, Olkin, Calinger, Howe, & Bell, 1999). Initially the study focused on the scaffolding teachers needed to plan and teach standards-based science. During this time, we realized that until teachers focused more on assessing student understanding few gains were likely to be made. Since most teachers find it a challenge to assess their students understanding of science, we extended the study to include how to facilitate this process.

Since teacher professional development usually results in few changes taking place (Guskey, 1995), we focused on creating a collaborative environment with strong support during planning and implementation (Gallagher, 1996; Ruskus, Luczak, & SRI International, 1995). Research suggests that meaningful collaboration facilitates educational reform (Fullan, 1991) and collaborative work cultures enhance student learning (Newmann & Wehlege, 1995).

Structurally the program was set up to include teams of teachers collaboratively studying over an extended time period (U.S. Department of Education, 1999). The program had an initial

concentration of study and planning time for teachers in the summer followed by six to nine months of implementation, analysis, and sharing of findings during the academic year.

We built into the program the characteristics of "best practices" and “best of the best” for exemplary teacher professional development programs in science and technology (Ruskus, et al., 1995). These best practices include:

- *Hands-on/minds-on instructional approach* which provides opportunities for participants to construct personal meaning from inquiry-based learning and assessment activities, models for effective teaching, and structured time for teachers to practice new classroom approaches and plan for teaching and assessment;
- *Immersion in science* which directly involves participants in conducting scientific investigations with scientists where the participants make observations, test hypotheses, design experiments, and collect, analyze, synthesize, and report data;
- *Systemic approach* which aligns curriculum, instruction, and assessment with local, state, or national standards and recruits teams of teachers from the same school and school district with the support of that system; and
- *Follow-up* that provides various forms of support throughout the school year that focus on classroom implementation.

In addition to alignment with the four basic features of best practice programs, this project modeled the three characteristics of programs identified as the "best of the best," which are a:

- *thematic design* around a single multidisciplinary theme,
- *supportive infrastructure* of material and human resources, and
- *evaluation plan that uses its findings* in revising the program.

To enhance the daily professional development environment of the summer workshops, many aspects of collaboration were built into the program. Social learning theory suggests the importance of observing and modeling behaviors, attitudes, and emotional reactions of others as part of self-efficacy (Bandura, 1977). Therefore staff members were carefully chosen and provided with their own professional development training so that they became a team immersed in the projects culture. Vygotsky's (1986) social development theory suggests that social interaction plays a pivotal role in cognitive development with peer collaboration exceeding what can be learned alone. Team problem solving and planning were an integral part of the program. According to Bruner (1960, 1990), learning is an active process where the learner constructs new knowledge by discovering principles themselves under the guidance of an instructor. Therefore instruction encouraged active dialog to uncover the structure and organization of new information in order for the learner to go beyond the information given. Experiential learning situations were established through classroom experiences where the learners became personally involved in self-initiated activities when they designed and conducted their own research investigations (Rogers, 1969). Cross (1981) emphasizes the importance for adult learning to be self-directed and problem-centered where they have as much choice as possible. Teacher teams were given the flexibility to adapt all assignments and research to their own schools and working situations. The perception of self-efficacy enhances cognitive development (Bandura, 1993).

Design and Procedure

The program was designed to provide participating teachers with professional development necessary to enable them to develop integrated, hands-on, inquiry-based science and mathematics teaching and assessment plans. During the summer workshops the teacher teams focused on developing integrated teaching and assessment plans that included the basic

elements of experimental design and data analysis. During the academic year the teachers focused on implementing their plans with support from their team members, other teams, and the instructional leadership team and assessing their students growing understanding.

Leadership Team

The first phase of the program was to develop a leadership team that co-planned and taught the summer workshops and follow-up sessions. The team consisted of university faculty from science, mathematics, and education and teacher leaders from the different participating school districts who were specialists in science or mathematics. Leadership skills were developed through increased knowledge of integrated science and mathematics gained by working with an interdisciplinary team during the planning and piloting process, critical analysis of student-centered teaching strategies and assessment practices, development and implementation of workshop plans, peer teaching and mentoring, and reflection and evaluation on every aspect of the program.

Teacher Teams

Our definition of a team was initially somewhat different from the teachers. We defined a team as two to three science and mathematics teachers teaching the same children. Most teachers defined a team as two to three teachers from the same school. When children are taught by a group of teachers, then not only is team planning for teachers' possible, but also with creative scheduling team teaching is possible. This difference in definition was accommodated during the summer workshop by contrasting an ideal situation for team planning and teaching with reality and allowing the teachers to adapt their plans to the realities of their teaching world. By continually contrasting collaborative planning and teaching, they became aware of what more they could accomplish as they could collaborate inside and outside the classroom. This also

resulted in many teams being able to devise very creative solutions to obstacles they faced. At this point with an increased focus on assessment, the reality of the classroom has caused a shift away from team teaching but toward team planning with teachers teaching the same grade level, preferably in the same school. The teachers plan together and then share and compare the work of their students.

Research Methodology

Using a constant comparative process (Glasser, 1978), data collected through surveys, interviews, focus groups, observations, and analysis of artifacts identified obstacles the teacher teams needed to overcome in developing integrated, inquiry-based science and mathematics teaching and assessment plans. A leadership team of scientists, mathematicians, and educators conducted the on-going formative research. The team analyzed the data on a daily basis during the summer program. This staffing arrangement provided triangulation among the staff observations and interviews where staff members independently identified problems that were in most cases observed by others.

Planning for Teaching and Assessment

On an earlier project (Sterling et al., 1999), we found that teachers tended to plan for teaching by stringing together their favorite classroom activities on the topic one after the other instead of identifying the essential science and mathematics concepts, placing the concepts in a logical order, and then choosing the most appropriate activity/strategy for teaching the concept. Therefore, we created a conceptual organizer (Sterling, 2000), as an advanced organizer, which enabled the teachers to see how to connect the concepts being studied together in a way that made scientific and mathematical sense.

As this study progressed, providing a structural framework for planning was extended to the assessment process. Through a continuous improvement model, the support scaffolding to guide planning for assessment was developed. This scaffolding, an assessment planning timeline, enabled teachers to effectively assess/conduct research on their students' understanding (see Figure 1). The teacher teams created teaching plans that incorporated multiple forms of diagnostic, formative, and summative assessment to monitor student learning in their classes. The research task initially was for teachers to identify a content standard and prove to their peers through assessment of understanding that their students had mastered the standard.

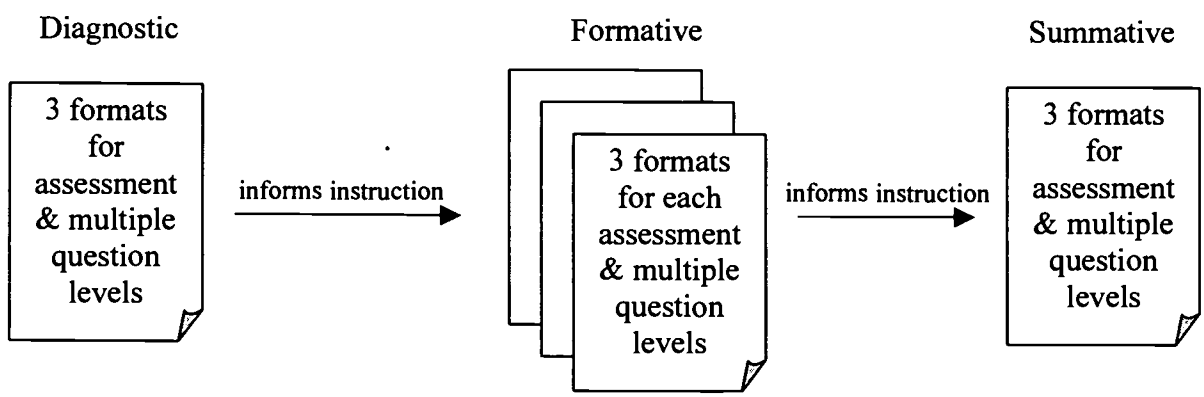

Figure 1. Assessment timeline for assessing student conceptual understanding. (Note. Three formats for each assessment is ideal for research triangulation. However, common sense needs to align subject matter, pedagogy, time, and resources. Therefore two, four, or some other number of assessment formats may be used on a particular assessment instrument.)

The assessment timeline provided a mental model for teachers to embed assessment as a natural part of their teaching. The timeline, a graphic organizer, combined the elements of a timeline with the need for multiple formats of assessment. The reason for the timeline aspect was because teaching takes place over time and time as we know it is sequential. The multiple formats for assessment is based on the research of Howard Gardner and others that shows that people learn in many ways and therefore demonstrate their understanding in many ways

(Armstrong, 1994; Gardner, 1983; Johnson, Johnson, & Holubec, 1993; Slavin, 1995). The multiple question levels is based on the work of Bloom (1956) that classifies thinking in a six level cognitive hierarchy from low to high level.

The assessment timeline could apply to the whole unit, a part of a unit, or one lesson. Therefore it could be viewed as a cycle or spiral with each assessment informing the teacher and student about the level of understanding or lack of understanding. This in turn would inform instruction and learning.

During the assessment planning process the teachers were continually asking themselves: What do I want the students to understand? During the teaching process the teachers asked: What do the students understand? Based on how closely matched were what the students understood with what the teachers felt they needed to know, a natural follow-on question was: What else can I do to help the students understand?

To enable the teachers to plan effective assessment formats and questions, state and national tests were analyzed. Then the teachers used the same analysis process on the assessment instruments that they created. Since Virginia has an assessment system based on multiple choice questions, sample state tests were analyzed using Bloom's taxonomy. The teams of teachers categorized each question for their grade level test according to the six levels of Bloom's taxonomy. These categories were then compared across grade levels. The teachers found that most of the questions across all grade levels were lower level questions though not just recall knowledge questions. The teachers then analyzed the format for each questions. They found only two formats of questions. Most common was an independent question ending with a question mark, but there were also a few complete the sentence questions. Since one of the state goals is for students to perform better on the state tests, this information will help teachers to

develop practice tests that are closely aligned to the state tests. The National Assessment of Educational Progress tests were then analyzed. Particular attention was placed on the different formats of questions from hands-on, to short answer, to multiple choice. In particular the teachers identified the value of pursuing a specific concept in a series of probing questions of different formats that probed more deeply into underlying understanding. The teachers used this same analysis process on the questions that they created.

Findings

Scaffolding for Planning

- A simple assessment paradigm/structural framework that teachers could easily visualize enabled them to embed assessment in their instruction.

As noted initially in this study, once the teachers had a vision of the kind of inquiry-based teaching called for by the national standards, the scaffolding that enable them to team plan fell into two categories - conceptual organizers and guided planning. It became apparent that when teachers were developing their own teaching plans that were not based around a core set of materials such as a textbook, they were left with an organizing structural void. To fill this void, an inquiry-based conceptual organizer, a type of advanced organizer, provided an organizing structure/scaffolding around which to base teaching plans (Sterling, 2000). Likewise it was found that teachers also needed an organizing structural framework around which to develop their assessment plans. The assessment timeline conceptually organized a process for teachers to identify and monitor student learning. The simplicity of the graphical organizer for assessment and the perception that it would work facilitated its success.

- By analyzing professionally developed assessment instruments that their students take, the teachers were better able to construct assessment instruments that they could conceptually defend.

To make the assessment process a reality the teachers analyzed multiple assessment instruments from different perspectives. The assessment analysis provided additional structure for the teachers that enabled them to create assessment plans and assessment instruments that they could conceptually defend to their peers.

Diagnostic Assessment

- Teachers assumed more initial understanding by the students than they really had.

Diagnostic assessment was particularly informative for the teachers. Teachers generally found that they assumed more initial understanding by the students than they really had. This caused them to reassess and adapt how they would start teaching the new topic.

- Constructing diagnostic assessment that hones in on emerging student understanding is difficult with most initial attempts showing what the students did not know and not their emerging understanding.

Many teachers found that developing diagnostic assessment instruments was challenging because of the need to hone in on the students emerging understanding. In many cases the first diagnostic instrument only showed that the students knew nothing on the topic and not their emerging understanding. Thus the teachers needed to create a new diagnostic assessment instrument to affectively target the students' prior knowledge and initial starting point for students on the standards being taught and assessed.

Formative Assessment

- Teachers were surprised at how prevalent misconceptions/misinterpretations were for students even after a topic had been taught.

Misconceptions and misinterpretations tended to be similar for many students as opposed to isolated events for single students. In many cases the teachers could see how the students misinterpreted a class activity. Thus by identifying common misconceptions or misinterpretations that students had of the subject matter being studied, the teachers were able to adapt their instruction to include activities and discussion designed to clarify the students' understanding. Though the adapted instruction could be done for the whole class, small groups of students, or selected individuals, the instruction was usually for everyone in an effort to clarify and reinforce concepts.

- Multiple short assessments targeted at student explanations of specific concepts were most helpful in following emerging student understanding.

Teachers found that writing was especially helpful in monitoring emerging understanding in science. By having students explain in writing what they understand about a particular concept enabled the teachers to assess whether their students understand a concept and if they didn't some insight into what they did not understand. Using a journal was particularly helpful to frequently target specific concepts. In many cases the teachers were already using journals but not using them for assessment purposes. A typical comment was, I "discover(ed) the science journal as an assessment tool." Another typical response included using "a greater variety of evaluations, more discussions and written journal entries that require students to explain their thinking processes."

- Having students explain why they choose a particular answer on a multiple choice question provided an effective way to assess deeper student understanding.

By grading both the multiple choice answer and the explanation, the teachers and students were able to assess understanding of the concept. For formative assessment during the unit, frequently asking one to two multiple choice questions with explanations provided practice for statewide multiple choice tests but also focused in on correct reasoning. This process built up to a longer version of a multiple choice test for the summative assessment.

- In addition to writing, having students discuss what they discover leads to better understanding.

By having groups of students actively explore concepts, they discover concepts and refine nuances in the process of sharing, which in turn leads to better understanding. Group processing of information and defending ideas is another way for students to solidify their understanding or misunderstanding. The danger here is the reinforcing of incorrect information. For this reason the teachers needed to monitor group processing of information for accuracy.

- Performance assessment was relegated to formative assessment because of the strong state emphasis on multiple choice paper and pencil tests.

Teachers reported being constrain by the assessment of state standards and their need to teach only to them. Since the state assesses students only using multiple choice questions for everything but the writing test, performance assessment was relegated to formative assessment and not summative assessment. In many cases performance was not assessed but was still done. On summative assessment tests performance items were converted to multiple choice questions as much as possible. For example for demonstrating the ability to use measuring devices the

students used real measuring devices for formative learning and sometimes assessment but used pictures of measuring devices for summative assessment.

Summative Assessment

- Having students complete a small number of multiple choice questions, approximately 10, where students explain why the answers they choose are correct appears to be helping students learn.

The data is inconclusive, because many teachers are being guided by their principals to give only 40-50 question multiple choice tests. This is in an effort to prepare the students for the 40-50 question multiple choice end-of-year state tests. However, for formative assessment toward the end of the unit or summative assessment using a small number of well chosen multiple choice questions, approximately 10, where students explain why the answers they chose are correct appears to be an effective format for assessing student understanding. It appears that students develop a deeper understanding when they go beyond identifying a correct answer to explaining a correct answer. The multiple choice questions on a summative assessment were usually augmented by one to two short essay questions. Other assessment formats such as drawing or performance attended to be relegated to formative assessment.

After participating in this program that focused on embedded diagnostic, formative, and summative assessment, the teachers reported observing the following changes in the performance of the majority of their students.

- Improved performance on classroom tests and other assigned work. (79%)
- Wider participation in classroom discussions. (79%)
- Greater willingness to volunteer. (71%)

These changes carried over to a lesser degree to their students from underserved and underrepresented populations.

- Improved performance of classroom tests and other assigned work (55%)
- Wider participation in classroom discussions. (73%)
- Greater willingness to volunteer. (55%)

Assessment Process

- Multiple assessments using multiple formats were more informative than any one assessment.

Overwhelmingly the teachers found that using multiple forms of assessment helped them assess their students understanding. Each form of assessment had its strengths and weaknesses, but using them together provided an abundance of information that the teachers did not expect about what their students understand and what they don't. It informed their instruction in a meaningful way.

- Implications from the state assessment tests altered how the teachers taught and assessed their students.

Since the state assessment tests were multiple choice questions, the tests provided no information about why the students missed a question or why they got it correct. Therefore the tests were not helpful in helping the teachers to help students learn more effectively. Furthermore many principals insisted on helping prepare students for the state tests by giving 40-50 question tests every other week. The focus on long tests took valuable time away from learning and didn't help either the teacher or the students understand why they missed a question. After focusing on embedding assessment in their instruction, the teachers became more

frustrated with traditional multiple choice testing but more focused on embedding short well-focused assessment in their teaching.

- The teachers reported improved relationships with colleagues by collaboratively working in teams.

Teachers reported increased collegiality, trust, and risk taking from their teamwork. Each teacher was on a two to three person collaborative action research team when they planned their units of study including the assessment instruments and procedures. One teacher described building a relationship with a colleague, "We opened up to each other regarding our teaching methods, which indicated a trust and belief in each other." Another teacher reported an "improved relationship with colleagues and students by allowing me to take risks with both." Other teachers reported a "sense of team effort." The teachers liked having a "chance to work with and discuss with other teachers to learn new ideas." One teacher went so far as to claim, "Any time teachers can get together to plan units, the results are magnified." As a direct result of participating in this project 79% of the teachers claim to have continued their professional development by "sharing information formally or informally with colleagues." Fifty-seven percent claim to have continued their professional development by "working with a team to revise curriculum."

- The teachers' confidence, motivation, and excitement grew as they participated in new hands-on learning activities and assessment.

Typical among teachers' reactions were the comment by one teacher who stated that "the new activities and knowledge makes me more motivated and excited about teaching and learning."

- Teachers reported using more concrete examples and real life situations.

Whether they were talking about teaching or assessment, teachers described using more concrete examples and real life situations. This also became evident in their planning as they discussed what real examples to use that children would find interesting.

- Teachers claimed to be better teachers when they focused on assessing student understanding and teaching for understanding.

According to one teacher a principal outcome from focusing on assessment is "looking at what learning will take place from what I do in the classroom and how I will assess that learning." Another teacher claimed to be a better teacher, because "it forced me to look at why I am doing an activity, the learning that will take place because of it and legitimate assessment to judge (the) extent of learning." Yet another teacher claimed, "It really has helped me teach for understanding. Which I believe has much merit!"

<u>Time</u>

- Teachers do not have enough time in their day to do all of the things that they would like to do to help their students learn.

Though this study focused on conceptual obstacles and not general obstacles, the lack of time was expressed so often that it merits mentioning. Time remains an on-going obstacle for teachers. In this program we incorporated planning time for teachers to collaborate and plan as part of the professional development during the summer. During the academic year, teachers were provided with substitute teachers so that they could attend 1-2 all day follow-up sessions. In addition since time was valuable, the leadership team planned to use all the time that was available as optimally as possible. All activities were directly related to strengthening the teachers' content and pedagogical knowledge or planning for instruction that would strengthen their students' knowledge.

What is evidence of student learning?

- Some teachers were sidetracked from focusing on student understanding to other peripherally related attributes such as fun and active student involvement.

Both fun and active student involvement are desirable outcomes. However, they may not be directly related to student conceptual understanding. While most teachers easily focused on assessing student understanding, peripherally related issues sidetracked some. Our next area of research focus will be on helping teachers to focus in on student conceptual understanding.

Conclusion

As new ways of teaching challenge traditional methodology, teachers need time to work through the conceptual change process. As the teachers are introduced to new methodologies and develop a new understanding of effective science teaching, they require multiple experiences that challenge their understanding of research-based teaching and assessment. A simple conceptual paradigm and a series of experiences that assists the teachers in investigating the new strategies at ever increasing depths helps teachers to progress through the change process. Our research identified conceptual obstacles for standards-based teaching and assessment and developed scaffolding that enabled teachers to understand and accommodate into their teaching style a student-centered approach to assessment. The scaffolding included an assessment timeline that conceptually organized the assessment process and a series of assessment instrument analyses.

Through collaboration and support the teachers changed their vision of assessment to one more closely aligned with the national standards for science and mathematics. They also included a more planned approach that was directly connected to assessing emerging student

understanding. Each time an obstacle is identified and an enabling strategy developed, teachers and student appeared to be moving closer to teaching and learning for student understanding.

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THE BRIDGES PROJECT: PAIRING PRESERVICE AND INSERVICE TEACHERS FOR PROFESSIONAL DEVELOPMENT IN SCIENCE, MATH, AND LITERACY USING PERFORMANCE ASSESSMENT TASKS AS CONTEXTS

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National and state educational reforms have recommended that students become more involved in their own learning based on the philosophy that student understanding is facilitated by active involvement. These reforms (e.g., AAAS, 1993; IRA/NCTE, 1996; NCTM, 1989,1991, 1995; NRC, 1996; WSCL, 1998 [hereafter referred to as "reform documents"]) call for teaching that will motivate students to become reflective, constructive, and self-regulated learners. Educational reforms require that students not only answer questions accurately, but be able to explain the process they used to derive their response. As school districts around the state and the country have developed and utilized techniques to improve student communication skills (especially in literacy), the focus has now become utilization of those skills in the areas of math, science, and technology. In a world that has become increasingly focused on information technology and telecommunications, it is imperative at the local, state and national level, that students are actively engaged and enthusiastic about learning and utilizing technology in math, science, and writing. There is already a severe shortage of graduates with expertise in these areas and that shortage is increasing at a rapid rate (NSF, 1996). The first and best response is to enhance and improve the training of teachers in math, science, and technology. Part of training the teachers to be able to teach math, science, and technology is to help them recognize what constitutes outstanding student work in these areas. The use of performance assessment is recommended to assess whether students can conceptualize important science and math concepts (i.e. Shymansky, Chidsey, Henriquez, Enger, Yore, Wolfe, & Jorgensen, 1997). Indeed, well-

designed assessment tasks can not only assess student understanding but also teach concepts (Darling-Hammond & Falk, 1997; Shepard, 2000). Performance assessment is particularly well-suited to this purpose because it focuses on having students apply knowledge in an authentic context for an authentic purpose.

Below we discuss needs for preservice science and math teacher education, and then we describe preliminary results from a program designed to meet those needs

Call for New Forms of Assessment

Following the release of NCTM's *Curriculum and Evaluation Standards* (1989), AAAS's *Benchmarks for Science Literacy* (1993) and NRC's *National Science Education Standards* (1996), many states and local school districts have developed standards for students' learning in mathematics and science. Included in these standards and in NCTM's recently published update to the *Standards*, the *Principles and Standards for School Mathematics* (NCTM, 2000), are a greater emphasis on the processes of doing mathematics (e.g., problem solving and reasoning) and on communicating thinking and solution strategies (NCTM, 1989, 2000). In the science realm is an emphasis on science as inquiry and understanding nature of science (AAAS, 1993; NRC, 1996).

Along with new standards for learning is a call for new forms of assessment. Traditional paper and pencil classroom tests and standardized multiple choice tests focused on recall of facts and basic procedures do not effectively measure what is valued for standards based learning (Darling-Hammond & Falk, 1997; Shepard, 2000; Torrance, 1993). While traditional measurement approaches to assessment were once aligned with the instructional practices of a century past, these approaches are not consistent with current teaching and learning goals from a social constructivist perspective (Shepard, 2000). This incongruity has resulted in an emerging paradigm for assessment that involves teachers' assessment of students' understandings and

students' self-assessments as part of the social process of knowledge construction (Shepard, 2000). Educators and researchers argue that to align assessment with the social constructivist perspective underlying standards based learning, the following changes are needed: (a) the form and content of assessments must represent higher order thinking, reasoning, communication, problem solving skills, as well as a conceptual understanding of subject matter; and (b) the focus of assessment policy needs to shift to using assessment for learning (Borko, Mayfield, Marion, Flexer, & Cumbro, 1997; Darling-Hammond & Falk, 1997; Shepard, 2000).

Consistent with these views, in mathematics and science education the *Standards* state that the primary purpose of assessment should be to support the learning of important mathematics and science. It should furnish useful information to both teachers and students. Assessment should be more than merely a test at the end of instruction to see how students perform under special conditions. To achieve this goal, the *Standards* call for embedding assessment in instruction, rather than keeping assessment as separate from learning (NCTM, 1995, 2000; NRC, 1996). Indeed, this call is supported by research that indicates use of formative assessments in instruction enhances student learning (Black & William, 1998).

As a result of this call, attention has been directed to more authentic forms of assessment, including performance assessment. Indeed, well-designed performance assessment tasks can not only assess student understanding but also teach concepts (Darling-Hammond & Falk, 1997; Shymansky, Chidsey, Henriques, Enger, Yore, Wolfe, & Jorgensen, 1997; Sheppard, 2000). While a single definition for performance assessment does not exist, Stenmark's (1991) definition for performance assessment in mathematics education seems to capture the important aspects of this approach. Stenmark (1991) states, "A performance assessment in mathematics involves presenting students with a mathematical task, project, or investigation, then observing

interviewing, and looking at their products to assess what they actually know and can do" (p. 13). We have used this definition for both our math and science education components.

Van de Walle (2001) expands on these ideas by proposing the following three criteria for a good performance assessment task. He states that a task must: (a) begin where the students are, regardless of their mathematical prowess; (b) be problematic due to the mathematics that the students are to learn, not due to the context of the problem; (c) require justifications and explanations for answers and methods (p. 66).

Beyond these definitions of performance assessment, educators and researchers argue that the advantages of classroom based performance assessments are that they provide the opportunity to:

1. Examine the process as well as the product and represent a full range of learning outcomes by assessing students' writing, products, and behavior (Danielson, 1997; Shepard, Flexer, Hiebert, Marion, Mayfield, & Weston, 1996).

2. Situate tasks in authentic, worthwhile, and/or real-world contexts (Stenmark, 1991).

3. Preserve the complexity of content knowledge and skills (Shepard, et al., 1996; Shymansky, et al., 1997).

4. Assess higher order thinking skills and deeper understandings (Firestone, Mayrowtz, & Fairman, 1998).

5. Embed assessment in instruction, rather than separating it from learning (Stenmark, 1991).

6. Apply criterion referenced assessment approaches based on important learning outcomes, rather than norm-reference (Stenmark, 1991).

Performance Assessment to Improve Teaching and Learning

Early research indicated that using performance assessment in instruction can improve student learning. Fuchs, Fuchs, Karns, Hamlett, and Katzaroff (1999) studied the effects of classroom based performance-assessment-driven instruction. They found that students in performance assessment-driven instruction classes demonstrated stronger problem solving skills than comparison groups that were not performance assessment-driven.

Kelly and Kahle (1999) found similar results in science. Students who took performance assessment tests were better able to explain their reasoning and conceptions than students who took traditional tests, leading to the conclusion that they had stronger understandings, perhaps as a result of working through the performance assessment task.

Shepard, Flexer, Heiber, Marion, Mayfield, and Weston (1996) also investigated whether using performance assessment in instruction improved student learning in mathematics. While they found little improvement in student achievement, they believed that more time was needed to realize change from students. However, they found that the teachers involved in the study were beginning to show substantial changes in practice. The changes included: greater use of manipulatives; increased emphasis on the teaching and learning of problem solving strategies; and increased class time and focus on written explanations in mathematics. Similarly, in Borko, et al.'s (1997) study of a professional development program on using performance assessment strategies in mathematics instruction, they found that their teachers changed their instructional practices to incorporate: using more problem solving activities; requiring student explanations of strategies as a central component of their programs; developing and using scoring rubrics for assessing students solutions of open-ended tasks. These changes all represent a shift in the direction of the vision for standards-based instruction.

While it is possible to derive many instructional benefits from performance assessment strategies, it is not clear that teachers can easily or quickly learn to implement these strategies in practice. Firestone, Mayrowetz, & Fairman (1998) studied teachers in states where state testing programs included performance assessment tasks, and therefore, teachers were being compelled to use performance assessment in instruction to prepare their students for state tests. The researchers found that moderately high-stakes testing combined with some professional development opportunities, generated considerable classroom activity focused on the test itself, and promoted changes to align curriculum with the tests; however, little change in instructional strategies resulted. Firestone, Mayrowetz, & Fairman (1998) identified two major barriers to change: a lack of the sophisticated content knowledge required in implementing performance assessment approaches; and a lack of rich tasks and problems in the curricular materials to support this approach to instruction. To elaborate on the first barrier, the researchers found that the teachers had limited views of what constituted practical applications of mathematics. The teachers' conceptions generally focused on shopkeeper math (e.g., balancing a checkbook, calculating the discount on sale items, or measuring ingredients for cooking), and their tasks emphasized lower level skills rather than the more challenging analytical and reasoning skills required for using mathematics in engineering, finance, marketing, and statistics. Firestone, Mayrowetz, & Fairman (1998) concluded that to effectively implement performance assessment and thereby realize the potential for improved student learning, teachers needed substantive training opportunities (not just new policies requiring new assessment approaches) and new curricular materials that are aligned with performance assessment strategies and a standards-based vision for teaching and learning.

Shymansky, et al. (1997) found similar results in their study conducted of science teachers and science educators. These teachers and science educators developed five different performance assessment tasks for grade 8-9. When administering the tasks, they found that students performed poorly on these tasks, calling into question whether the tasks were poorly designed, or whether the students simply did not know how to take the tests. They also found how complicated it was to design performance assessment tasks that were truly valid.

In accordance with Firestone, Mayrowetz, and Fairman's (1998), and Shymansky et al (1997) research results, Borko, et al. (1997) found that substantive and sustained professional development is needed for teachers to effectively use and realize the benefits for performance assessment approaches. Their research indicated that important features of their program included: situating the change process in the actual teaching and learning contexts where the new ideas will be implemented; fostering supportive learning communities of teachers as they learn about new approaches and as the attempt to make changes; and providing staff development personnel with specific expertise to facilitate change by introducing new ideas based on teachers' current levels of interest, understanding and skill. Along with these features that enhances their program, Borko, et al. (1997) identified two barriers not discussed by Firestone, Mayrowetz, & Fairman (1998). First, Borko, et al. Found that teachers' beliefs need to be recognized and a primary focus of professional development efforts in performance assessment approaches. They believed that their project would have been more successful in effecting change in practice if they had addressed teachers' beliefs more directly. As Firestone, Mayrowetz, & Fairman reported, Borke, et al. found that many of their teachers had a limited view of mathematics and appropriate strategies for teaching mathematics that were inconsistent with the standards-based vision of mathematics. These views needed to be confronted for substantive change to occur.

Without confronting these beliefs, teachers tended to either ignore new ideas of assimilate them into existing practice, instead of making major shifts in practice. Second, Borko, et al. found that time was a major obstacle to changing classroom practice. In particular, competition among priorities for limited classroom time was problematic. For implementing performance assessment approaches, time served as a barrier in: planning for the implementation of new strategies; applying more complex scoring rubrics in assessment; administering the assessment tasks; recording observations of students working and thinking as part of the assessment; and interviewing students before, during, and after the assessment. For successful change to occur, teachers need time for implementing new assessment approaches.

Recognizing the value of performance assessment and the complexity of using these strategies, we decided to make performance assessment a focus of our mathematics and science methods courses. This decision was part of our effort to prepare our preservice teachers from the beginning of their careers to use these approaches and to implement standards-based teaching and learning in their own instructional practice.

Situated and Constructivist Perspectives on Teacher Learning

With the goal of developing preservice teachers' abilities to implement performance assessment in their classrooms, we considered a second need identified in teacher education literature: a need to situate preservice teacher learning in classroom practice. Borko, et al. (1997) emphasized the importance of this approach for professional growth. They found that a key component of their program was their teachers' ability to experiment with and implement the ideas of the professional development workshops in their own classroom practice, and then to reflect on these efforts in follow-up workshops.

This finding is consistent with the perspective of teacher learning put forth by Putnam and Borko (2000). They argue that for teachers to construct new knowledge about their practice the learning needs to be situated in authentic contexts. First, learning needs to be situated in authentic activities in classrooms to support transfer to practice. For preservice teachers, a combination of university learning for theoretical foundations and school-based learning for a situated perspective is needed (Putnam & Borko, 2000). Second, preservice and inservice teachers should participate in discourse communities as part of learning and enculturation in the profession. Preservice teachers, in particular, need to learn about and contribute to a community's way of thinking (Putnam & Borko, 2000). This process of enculturation is especially important for future teachers of mathematics or science because many come to their education program with limited views of teaching, learning, and doing mathematics (Roth-McDuffie, McGinnis, & Graeber, 2000).

Spector (1999) recommends having preservice teachers work with inservice teachers to help them better apply newly learned teaching and assessment strategies. This finding falls in line with Dickinson, Burns, Hagen, and Locker (1997) finding that within the teaching context and support of an enthusiastic peer, important changes in science teaching can take place.

Putnam and Borko (2000) recognized that implementing this perspective in teacher preparation programs can be problematic. While we want to place preservice teachers in schools to experience the activities of teaching as part of their learning, K-12 placement classrooms may not embody the kind of teaching and learning advocated in university classrooms and/or these kinds of classrooms may not be available. Moreover, the pull of traditional school culture is strong, and these traditions make it difficult for student teachers to go in with different approaches and views (Putnam & Borko, 2000).

One solution to achieving a situated context while overcoming the problems of school placements is to use case-based approaches for preservice teacher learning. This approach provides shared experiences for preservice teachers to examine together and allows for the teacher educator to control the situations and issues that arise (Putnam & Borko, 2000; Sykes & Bird, 1992). Another approach is using professional development schools that also provide for greater control and monitoring of the preservice teachers' experiences (Putnam & Borko, 2000). While we want to mention these options for consideration, these approaches are not the focus of this program.

The paper describes the design and preliminary results of the project in its first year of implementation, and will note future directions the project will take. *The Bridges Project* is a Professional Development Program that pairs inservice and preservice teachers together in small groups to develop performance assessment tasks that include the content areas of mathematics, science, technology, and writing. By bringing inservice and preservice teachers together to collaborate on a meaningful design project, we are creating a new model for professional development by creating a "bridge" that enables the development of networking and mentoring opportunities, and builds a sense of community. The "bridge" of professional development activities for preservice and inservice teachers will establish and cement important relationships among participants that are foundational in assuring their long-term success.

The purpose of the study was to determine (a) preservice teachers' understandings of performance assessment, (b) methods of developing understandings of performance assessment, (c) a model for collaboration between preservice and inservice teachers in developing performance assessment tasks, and (d) identification of and recommendation for remediation of constraints to the program.

Procedures

Description of the Course

The current study took place in a one-semester K-8 science methods course. There were nineteen students enrolled, working on a Master in Teaching (MIT) degree. This science methods course was the only course they would take to prepare them to teach science. In addition to designing and administering the performance assessment task with the help of their mentor teacher, other assignments in the course were: (a) study a content area, design and administer an interview of a K-8 student to identify student ideas, (b) design lessons to address those ideas, (c) participate in hands-on, minds-on activities in class, (d) submit weekly reflection papers on assigned topics, (e) participate in weekly hands-on activities designed to improve nature of science conceptions.

Intervention

The second author was concurrently teaching an Advanced Educational Psychology course. During this course she introduced performance assessment as a tool for finding out student conceptions.

In the science methods course later in the semester, students were again presented with information about performance assessment. This time two inservice teachers who had been identified as experts in using performance assessment came to teach the preservice teachers. They shared an overview of how performance assessment tasks can help teachers address state and national standards. They engaged the preservice teachers in a performance assessment task and asked students to score student work from the same task. In addition, the second author talked about the importance of writing in conjunction with the task. This performance assessment night was videotaped.

Finally, the preservice teachers were required to design a science performance assessment task with help from mentor teachers. The mentor teachers provided feedback on both the task and its administration. The preservice teachers administered the tasks in the mentor teacher classrooms. The preservice teachers wrote two reflection papers during the course of the assignment, and wrote a formal paper at the conclusion of the assignment that included an analysis of student work as well as reflections on the process and recommendations for improving the task.

Data Collection

To track results of design, administration, and conceptions of what constitutes a performance assessment task a variety of data were collected. Prior to the introduction of the program a baseline understanding of the preservice teachers' conceptions of performance assessment was designed through surveys and interviews of all ten students who met interview criteria. The interview criteria consisted of (a) being officially enrolled in the Master in Teaching cohort, (b) being concurrently enrolled in advanced educational psychology course, and (c) the intention to take math methods in the spring. (See Appendix A for interview protocol.)

In addition to the interviews, both researchers kept independent logs of their perceptions of preservice teacher understandings of performance assessment and the challenges of program implementation.

To track preservice teacher effectiveness of writing the task, the performance assessment tasks were collected for analysis. To track administration of the task student reflections were collected, and videotapes were made of as many preservice teachers as possible.

To address logistical issues of the field-based component the researcher logs, discussions and emails with preservice teachers, and final performance assessment task reports were

collected. This data allowed development of a profile of the project in order to make recommendations for future implementation.

Data was collected from the inservice teachers involved in the project through a survey (see Appendix B) sent to them through the mail after the preservice teachers had completed their field work in the classroom. The inservice teachers were asked about their understanding of performance assessment, how they implement it in their classroom, and their rating of the preservice teacher's performance assessment task implementation. The inservice teachers were asked if they had learned anything about performance assessment through their mentorship experience and if they had suggestions for future similar projects.

Data Analysis

To conduct the preliminary analysis of this on-going research project the researchers and a graduate student sorted through all data currently collected. This data was used in an interpretive fashion to develop early categories in response to the research questions.

To determine preservice teachers' understandings of performance assessment, preservice teacher responses to interview questions were coded using the scheme developed by Fuchs, Fuchs, Karns, Hamlet, and Katzaroff (1999). Interview responses were coded a one (1) or a zero (0) indicating preservice teachers included items that showed understanding of performance assessment in their responses. The final tasks were coded with the same scheme indicating items that showed whether an understanding of performance assessment was included in the tasks. It should be noted that the coding scheme does not determine how well the tasks were developed, but whether the responses or tasks included components that indicated how well they understood performance assessment.

The portions of the research questions of determining (a) methods of developing understandings of performance assessment, and (b) a model for collaboration between preservice

and inservice teachers in developing performance assessment tasks are still under study and will be presented at a later time.

To identify constraints of the program and provide recommendations for their remediation, student reflection papers, the final tasks, researcher logs, videotapes, informal discussions, and emails with students were used. Patterns were sought in these data sources to determine any difficulties or successes within the program administration.

Preliminary Findings

Understandings of Performance Assessment

Prior to intervention the preservice teachers had very little understanding of performance assessment as indicated by low scores on the coding scheme (Fuchs et al, 1999). The preservice teachers included very few of the components necessary to a performance assessment task: their examples tended to be short, required single answers, and did not provide opportunity for their students to generate ideas. Additionally, none of the preservice teachers required students to explain their work, nor to generate a written communication about their work. Their idea of performance assessment was not couched in an authentic task.

From videotapes, questionnaires, and interviews, it was apparent that the preservice teachers continued to hold minimal understandings of performance assessment even after being introduced to it in their Advanced Educational Psychology class and after the performance assessment night in the science methods course.

Following the interventions, and especially upon developing and administering their own tasks, the preservice teachers' understandings of performance assessment improved greatly, as indicated by scores on the coding scheme (See Appendix C). All preservice teachers required from their students written explanation of strategies, modeling of strategies, and multiple

questions that required application of knowledge set in an authentic context. Most of the tasks developed by the preservice teachers required their students to generate ideas and information rather than memorize or provide single answer responses.

Logistical Issues of Field-Based Component

The changes in conceptions of performance assessment were made with some struggle, this was in part due to logistical issues within the collaboration between the university and the Educational Services District (ESD). Both the university and ESD participants were committed to making the program work well, but it was not easy coordinating all the sections of the program. From all data sources it was apparent that there was much frustration on the part of the preservice teachers as well as the course instructor in organizing the performance assessment task. The preservice teachers had difficulty understanding performance assessment in science, in part because the master teachers who presented the examples, while excellent mathematics instructors, were not science instructors, and thus examples given were only loosely connected to science. Additionally, one of the master teachers continually referred to "proof" in science, when the preservice teachers had just recently been party to a class session on nature of science that illustrated there can be no absolute proof in science. They found this reference confusing and frustrating, one student noting "I thought we learned last week there was no proof in science!" However, some of their misunderstanding of performance assessment in science was also related to lack of understanding of performance assessment itself, despite the training sessions. Most preservice teachers' initial drafts did not, for instance, couch their tasks in an authentic context. With feedback from the course instructor, these kinds of errors were corrected.

The course instructor also found frustration in having math teachers present tasks as illustrations of performance assessment, however well and masterfully done, in the science

methods course, it would have been much better to have science teachers present model tasks for students to complete. Additionally, it is hoped that science teachers would recognize the lack of absolute proof in science, and thus, not keep forcing the issue with the preservice teachers, but instead reinforce their appropriate response that there is no way to prove something in scientific inquiry, just to add support.

Preservice teachers also found frustrations in scheduling meetings with their mentor teachers, and in obtaining appropriate feedback on their tasks. In fact, many preservice teachers found that their mentor teachers did not understand performance assessment, and were learning from the preservice teachers. They also found some difficulties in administering science tasks in classrooms that may not have yet studied a particular content, requiring them to take extra time to teach a lesson, and then administer their task. A frustration for preservice teachers trying to administer a task about plants was the time frame for the project. It was difficult to get a plant project authentically done in a classroom because there wasn't sufficient time to grow and compare plants.

Another frustration for the course instructor was the necessary strong emphasis on performance assessment in the science methods course vs. other emphases. The course instructor generally makes a stronger emphasis on elements of nature of science, yet was unable to do as thorough an emphasis due to time spent on performance assessment. Whether this lesser emphasis has made a difference in preservice teacher conceptions of nature of science has yet to be determined, but data has been collected for future analysis and comparison to former classes. Will the course instructor find that the performance assessment task has made a difference in preservice teacher knowledge of nature of science?

Perceptions of Mentor Teachers

The inservice, mentor teachers provided feedback on the project on the survey they were sent in the mail. Some of the teachers had had an introduction to performance assessment in the past, usually through workshops provided in their schools. Some had had no experience with performance assessment. The overall impression was that they did not fully understand performance assessment and could not adequately rate the preservice teacher's implementation of the performance assessment task. The feedback on the project was positive from the mentor teachers, one teacher said they thought it was " another excellent way for students to get into the classroom."

Perceptions from the Educational Service District (ESD)

The collaboration between the ESD and the university allowed this project to begin to build strong relationships between university faculty and students, inservice teachers, and ESD employees. This relationship will develop in the future and undoubtedly result in stronger understandings between all involved. The ESD was able to offer a stipend to the participating inservice teachers which compensated them for the time they put into the project. Inservice teachers should not be expected to devote time outside of their regular duties without compensation.

The data show that the mentor teachers involved in the project had little experience or knowledge about performance assessment. In light of this, the ESD has committed to involve more inservice teachers in performance assessment training workshops and experiences

Implications

While students did grow in their understandings of performance assessment, there is still much work to be done. Most importantly, details regarding partnerships built between inservice and preservice teachers need to be ironed out. Specifically, inservice teachers of the right grade

levels and content areas, who have appropriate levels of knowledge of performance assessment need to be found. Also, better mechanisms for matching these inservice teachers with preservice teachers need to be developed in order to eliminate preservice teacher frustrations and allow them to focus on the performance assessment itself.

Probably the most positive comments from the preservice teachers regarding the whole assignment were that they were pleased to be working with actual students. This finding is in line with the Putnam and Borko (2000) finding that a situated perspective is most meaningful to learning. When asked whether they would rather teach a lesson to actual students or to administer the performance assessment task, the preservice teachers indicated they would prefer to do both. They believed the performance task was valuable, and that they learned a lot from the experience. It seems it may be necessary to actually create and administer the task for preservice, and even inservice, teachers to develop an appropriate understanding of performance assessment.

As you can see from the title of our paper, we intended to embed many different topics, such as literacy, under the performance assessment umbrella. There is a great temptation to use the context for an authentic task to check for embedded nature of science elements, and of math and science content issues. There is a further temptation to note development of literacy given the written component of each task. However, we have found that simply teaching the performance assessment task itself is complex enough without asking preservice teachers to do further work within the context. Indeed, we are even having challenges with helping the preservice teachers develop well-designed rubrics to assess their own students. When we get our instructional process better developed we will begin again to look at embedding the other elements. Additionally, we hope to instruct inservice teachers in the use of performance assessment, and may find it is easier for them to embed other tasks within the context.

Future Directions

So what next? As we continue to analyze data we continue to redirect our attentions to new problems. We are still interested in seeing whether students made important gains in their understandings of nature of science, and that data analysis is now under way. The preservice teachers from this preliminary report will be enrolled in a math methods course next semester. They will again be required to create and administer a performance assessment task, this time in math, with the help of an inservice teacher mentor. We will interview the students again to see whether their views and examples of performance assessment tasks have improved. We will schedule meetings for the preservice and inservice teachers to work together to develop the tasks. We will videotape these meetings, and the administration of the tasks. We will allow preservice teachers to develop the performance assessment tasks in teams to share the burdens and hopefully alleviate some of the challenges uncovered in the first task.

A similar study will be run on a group of preservice K-8 teachers who will be concurrently enrolled in science and math methods. They will be allowed to work in teams, and to develop either one task to satisfy both course's objectives (making sure to have the task assess for both math and science objectives), or two tasks, one for science methods and one for math methods. We will continue our data collection and analysis as planned, and will continue to seek to know whether and how understandings of performance assessment improve, and how that affects understandings of nature of science that is the usual emphasis in the science methods course.

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Appendix A

Pedagogical Beliefs in Mathematics Survey / Interview Questions
(Adapted from Peterson, et. al., 1989)

1. A. Describe, as specifically as you can, a lesson in which you introduce a *new* mathematics topic to your class. We are interested in the way you organize and present the mathematics content, as well as the specific teaching methods and strategies that you use. Preservice teachers: *imagine* a lesson and describe it (if you have not had experience teaching a new mathematics topic). Inservice teachers: *recall* a particular lesson and describe it.

   B. How does your *introductory* lesson differ from a *typical* lesson on a mathematics topic?

2. Describe, as specifically as you can, a lesson in which you introduce a new science topic to your class. We are interested in the way you organize and present the science content, as well as the specific teaching methods and strategies that you use. Preservice teachers: *imagine* a lesson and describe it (if you have not had experience teaching a new science topic). Inservice teachers: *recall* a particular lesson and describe it.

   B. How does your *introductory* lesson differ from a *typical* lesson on a mathematics topic?

3. Describe, as specifically as you can, a lesson in which you include elements of the Nature of Science. We are interested in the way you organize and present the philosophy, as well as the specific teaching methods and strategies that you use. State specifically the elements you included. Preservice teachers: *imagine* a lesson and describe it (if you have not had experience teaching science). Inservice teachers: *recall* a particular lesson and describe it.

4. Describe, as specifically as you can, a lesson in which you include writing in mathematics and/or science activities. We are interested in the role of writing in the lesson and the type of writing expected, as well as teaching methods and strategies that you use with writing. Preservice teachers: *imagine* a lesson and describe it (if you have not had experience teaching a new mathematics and/or science topic). Inservice teachers: *recall* a particular lesson and describe it.

5. What do you think the role of the teacher should be in teaching problem solving and reasoning to students?

6. What do you think the role of the learner should be in a lesson involving problem solving and reasoning?

7. Are there certain kinds of knowledge and/or skills in mathematics that you believe all students should have? If so, what are they?

8. Are there certain kinds of knowledge and/or skills in science that you believe all students should have? If so, what are they?

9. For the grade that you teach (or intend to teach), what do you believe should be the relative emphasis in mathematics on fact knowledge versus understanding topics and processes versus solving of real-world/ authentic problems? Why?

10. What do you see as the relationship between learning of mathematics facts, understanding mathematics concepts and processes, and solving real-world/ authentic problems involving mathematics?

11. For the grade that you teach (or intend to teach), what do you believe should be the relative emphasis in science on fact knowledge versus understanding scientific concepts and processes versus solving of real-world/ authentic problems? Why?

12. What do you see as the relationship between learning of scientific facts, understanding scientific concepts and processes, and solving real-world/ authentic problems involving science?

13. What do you think the role of technology (e.g., calculators, computers, internet-use, etc.) should be in teaching and learning mathematics?

14. What do you think the role of technology (e.g., calculators, computers, internet-use, etc.) should be in teaching and learning science?

15. Students have different abilities and knowledge about mathematics. How do you find out about these differences?

16. Students have different abilities and knowledge about science. How do you find out about these differences?

17. Describe, as specifically as possible, what you understand performance assessment to be, when you believe it is useful, and when you believe it is not appropriate to use. If you have used performance assessment in your teaching, describe how you have used it.

Performance Assessment Interview: Additional Items (Fuchs, et al., 1999)

18. Write and/or describe a mathematics problem that might be categorized as an example of performance assessment.

19. Write and/or describe a science problem that might be categorized as an example of performance assessment.

Appendix A (continued)

Nature of Science Survey Interview/Questionnaire Questions

1. After scientists have developed a theory (e.g. atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach theories. Defend your answer with examples.

2. What does an atom look like? How certain are scientists about the structure of atoms? What specific kinds of evidence do you think scientists used to determine what an atom looks like?

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.

6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

7. Some astronomers believe that the universe is expanding while others believe it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

Appendix B

Performance Assessment Task Mentorship Survey

Name______________________________School____________________________________

Grade/Subject______________________WSU Preservice Teacher____________________

1. How would you define the term "performance assessment"?

____

2. How often do you do performance assessment in your classroom?

Often (weekly)___Sometimes (monthly)____Seldom (1-2 times/year)____Never____

3. Have you had any classes/workshops/inservices on performance assessment?______

If yes, please describe____

4. Briefly describe your preservice teacher's performance assessment task:____________

5. How would you rate the success of the preservice teacher's performance task implementation? (This will be held completely confidential)________________________

6. How well do you feel the student's task met the criteria for performance assessment?
Did the task: a. present students with a task, project, or investigation? **YES NO N/A**

b. establish a meaningful context based on issues/problems, themes, and/or students' ideas? **YES NO N/A**

c. require the application of thinking skills/processes? **YES NO N/A**

d. call for products/performances with a clear purpose for an identified audience? **YES NO N/A**

7. Did you learn anything about performance assessment tasks through this mentorship experience? If so, please describe:____

8. Do you have any suggestions for the improvement of this mentorship project for the future? Please use the back of this form to complete this question.

Appendix C

Coding Scheme for Performance Assessment Elements Present in Tasks or Descriptions of Tasks (Adapted from Fuchs, et al., 1999)

Code "1" if present, "0" if not present:

Write (describe) a math/science problem that might be categorized as an example of performance assessment:

Contains 2 or more paragraphs
Contains Tables or graphs
Has 2 or more questions
Provides opportunities to apply 3 or more skills
Requires students to discriminate relevant/irrelevant information
Requires students to explain work
Requires students to generate written communication

ELEMENTARY SCIENCE TEACHER LEADERSHIP (ESTL) PROGRAM: A PROFESSIONAL DEVELOPMENT MODEL

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Elementary Science Teacher Leadership (ESTL), the teacher-enhancement project supported by the ExxonMobil Foundation, began in 1997. The project is part of a long-term teacher development effort of the Science Education for Public Understanding Program (SEPUP) at the Lawrence Hall of Science, University of California, Berkeley. The purpose of this project is to enhance the understanding of science and approaches to teaching for in-service and pre-service elementary teachers by building on-going relationships between teacher-training institutions and the schools they serve. This is particularly important because very often the collaborations between the universities and the schools they serve are not strong and do not go beyond administrative and placement decisions. Many elementary schools do not see their roles as providing the time and leadership for practical, reflective classroom experiences for student teachers so that they can have substantive opportunities to develop their capabilities within the context of student teaching. As a result of this, developing teachers who understand best practices in science teaching has been particularly difficult. Additionally, it has also been noted that teachers who are already part of the teaching force do not apply best practices when teaching science and essentially do not exhibit adequate science teaching skills (Abell & Roth, 1992; Atwater, Gardner, & Kight, 1991). The purpose of this project is to address these issues.

The long-term project goals emphasize helping teachers to view themselves as life-long learners and their profession as a career with opportunities for long-term growth. For this to happen, it is necessary to change the way teachers are prepared to teach science for the classrooms of tomorrow. The ESTL project is doing this by identifying exemplary pedagogical strategies for teaching science. Very often, we see elementary teachers using outstanding pedagogical skills when teaching language arts or social studies, but these skills do not crossover to the teaching of science. These resource materials are developed and designed to help teachers build on the strengths demonstrated in other subject areas in order to excel in science instruction. To make this a reality, the project has developed a set of guides with materials kits that address important issues in science and can be used for further developing in-service and pre-service teachers of students in grades 4-6. These materials have been extensively tested at the ESTL field test centers and based upon their feedback the Guides are now in the process of revision. Below is a list of the resource guides with a brief description of each guide:

Elementary Science Teacher Leadership Guides

1. *Integration Across the Curriculum.* The participants construct a rationale for the use of integration in science education and develop an integrated unit.
2. *Facilitated Teaching: Asking Better Questions.* The participants understand how to facilitate learning and encourage student inquiry by learning how to ask thoughtful and open-ended questions.

3. *Learning About Assessment.* Participants are provided with activities and information about assessment that provide contexts for discussion about the issues of assessment and evaluation.

4. *Equity For All in Science Education.* The participants learn to have a heightened awareness about the issues of equity and develop practical approaches to dealing with diversity in the classroom.

5. *The Nature of Science.* Participants have experiences in science that help them construct their own understanding of the nature of science. Through these experiences they will also understand the link between the nature of science and the nature of learning.

6. *Understanding and Using the National Science Education Standards.* This guide is designed to help participants to become familiar with the National Science Education Standards and to understand its importance to them as teachers of science.

7. *Teacher/Leaders and Peer Support.* This guide helps participants to understand that it is necessary to see themselves as life long learners, to work collegially, and to collaborate with others in order to become effective teachers of science in their school communities.

8. *Building for Conceptual Understanding in Science.* This guide gives participants a deeper knowledge of how children understand scientific phenomena and the implications of this for teaching and learning in science.

9. *Linking Science and Literacy.* This guide highlights the importance of science in the total elementary school curriculum. It demonstrates the effectiveness of using quality science

instruction as part of an integrated effort to support and contribute to the improvement of students' literacy skills.

10. *Science and Numeracy.* This guide under construction will focus on the importance of quantitative reasoning in science. It will help teachers see how their science program can contribute to students' understanding of mathematics.

11. *Composite ESTL Guide.* This guide was produced for a science methods course and includes parts of *The Nature of Science, Facilitated Teaching: Asking Better Questions, Integration Across the Curriculum, Literacy Through Science*, and *Learning About Assessment*. It includes resources that can be used to provide 27 dynamic hours of instruction.

Each guide has a teaching focus and a science content theme that weaves throughout and is reflected in the adult and student learning activities. The content themes, taken from the National Science Education Standards, enhance the teacher-participant's science content knowledge by using Middle School and High School SEPUP activities that model best practice in science teaching. As part of the guide, the question: 'What would this look like in my classroom?' is answered by including CHEM 2 activities, which is the fourth- through sixth-grade SEPUP program. In this way, teachers using ESTL materials are being helped to gain an understanding of inquiry as articulated in the National Science Education Standards that states:

"Prospective and practicing teachers must take science courses in which they learn science through inquiry, having the same opportunities as their students will have to develop understanding" (NRC, 1996, p. 60). As part of ESTL, they will become skilled teachers of science who "have special understandings and abilities that integrate their knowledge of science content, curriculum, learning, teaching, and students" (NRC, 1996, p. 62). Having the ESTL Guides used as part of their pre and in-service teacher professional development, the teacher/participants will have opportunities to apply their knowledge of learning to become effective educational leaders who develop the capacity to be decision makers about teaching strategies, curriculum materials, learning goals, and the selection of appropriate assessment tasks for their students.

The guides are designed to be used for a variety of purposes and settings. First, they can be used by either pre-service or in-service teacher educators in methods courses, required classes, development workshops, or a variety of in-service programs. Second, the guides can be used by picking from one or many guides, or by concentrating on a full guide or a sequence of them together. For example, someone doing a workshop on assessment could use the Learning about Assessment Guide to provide a scientific context for studying assessment issues. Alternatively, the Composite Guide, for example, was created for a methods class at California State University, Hayward and represents one instructor's vision of what is important for a methods class. All of the guides are very flexible in nature and are intended for use as a resource, so that parts of the guides can be integrated into existing university methods courses, school in-

service programs or other professional development efforts. Each guide, when done in its entirety, represents nine dynamic hours of instruction, but it is possible to create a custom guide selecting parts from many different guides.

The guides present many theoretical concepts, but for each statement of theory an activity is presented so the participants can concretely internalize the important concepts. Throughout the guides there are hands-on activities, readings, time for discussions and personal reflection. They emphasize that experience and human interaction are the basis for learning, and they model "science as a human endeavor" (NRC, 1996, p. 200). The ESTL structure provides important opportunities for teachers and their cooperating professionals as identified in the following statement from the National Science Education Standards for excellence in science teaching: "When teachers have the time and opportunity to describe their own views about learning and teaching, to conduct research on their own teaching and to compare and contrast and revise their views, they come to understand the nature of exemplary teaching"(NRC, 1996, p. 67).
The ESTL vision is to provide resources to help cooperating professionals work with teachers to more effectively develop ideas about exemplary science teaching. The goal is for this to take place during the student's pre-service teacher education and then to continue to support them as they move into the schools for the first three years of their career as professionals. This represents a five-year period of time when good classroom teaching practices are usually developed, improved and refined and the individual becomes a tenured professional in the school system. In the long-term, ESTL expects to contribute to helping beginning teachers understand

what constitutes exemplary science instruction and ways in which they can access it. ESTL has embraced "the challenge of professional development ... to create optimal learning situations in which the best sources of expertise are linked with the experiences and current needs of the teacher" (NRC, 1996, p. 58).

ESTL will accomplish this by collaborating with professional groups such as the National Science Teachers Association (NSTA), the Association for the Education of Teachers in Science (AETS), and others to design and offer a series of ExxonMobil Elementary Science Teaching Institutes. Institute participants will include university professors, school system leaders, and others responsible for designing and implementing elementary teacher development programs at the local level. In this way, ESTL will continue to change and update its materials dependent upon feedback from the field and new theoretical resources, as they become available.

Professional development for teachers is a continuous process that spans the life of a teacher from undergraduate education to the end of their professional career. When professional developers use ESTL strategies, they are using a structure designed to help change the vision of science teaching in the 21st century. The ESTL structure provides for long term professional development of teachers throughout their professional careers. The ESTL team invites interested members of AETS to join us in what we see as a partnership with you to help improve the quality and quantity of pre- and in-service teacher development. As soon as they are scheduled, information about the planned ExxonMobil ESTL Institutes will be posted on the SEPUP Web page (www. lhs.berkeley.edu/SEPUP) and the AETS listserv.

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SECONDARY SCIENCE TEACHER CANDIDATES' BELIEFS AND PRACTICES

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Science education reform efforts have culminated in a recent consensus regarding the vision of science education for students in kindergarten through grade twelve. The *National Science Education Standards* (National Research Council, 1996) was produced by a collaboration of people involved in the science education community including teachers, professors, scientists, and business professionals. It is unique from previous reform literature in that a key element includes recommended systemic changes within the science education community that are necessary to create a scientifically literate society. A strong message in the *Standards* is that science is for all children, regardless of ethnic background, academic ability, or gender. Recommendations are made for teachers, administrators, university faculty, and government officials to insure that the goal of science for all is to be realized.

In regards to the professional development of teachers, the *Standards* (1996) state that "Effective science teaching is more than knowing science content and some teaching strategies. Skilled teachers of science have special understandings and abilities that integrate their knowledge of science content, curriculum, learning, teaching, and students." (p. 62). How are these "special understandings" produced? What factors assist in the development of these understandings? What is the role of teacher education programs in identifying and building on previous knowledge regarding teaching and learning?

A goal of teacher preparation programs should be to create the best teachers possible. Teacher preparation programs should inform students of current reforms, constructivist practices, assessments, and associated research which contribute to the knowledge of effective teaching practices. The current status of science education is that constructivist teaching strategies define

best practice (Cannon, 1995). Best practice, as defined through the lens of constructivist strategies, includes a greater emphasis on the role of the student. In a constructivist-based, student-centered classroom, students are responsible for their own learning. In order for students to decide what is important to learn, students must be given the autonomy to set goals, define investigations, explore scientific phenomenon, present results, and make decisions regarding their evaluation. In a student-centered classroom, the role of the teacher is that of a facilitator, providing guidance for students' autonomous learning. Yager (1991, 1995) described constructivist teachers as those who: seek out and use student questions as the central strategy in deciding instruction; modify instruction based on students' thinking and interests; are able to ask thought provoking questions and ask students to clarify and elaborate on their responses; encourage students to predict, test ideas, and speculate on causes for events; use cooperative learning strategies in order for students to question each others ideas in an atmosphere based on respect; assess prior understandings of students and design instruction to challenge misconceptions as they become apparent; have students fully explain their ideas about concepts before introducing their own ideas or information from textbooks or other sources.

In contrast, in a didactic, teacher-centered classroom, the teacher decides the content to be covered, the experimental designs, and the assessment of student learning. The students follow teacher directions. The emphasis is on the acquisition of content knowledge. Student to student interaction is not permitted (Aaronsohn, 1996).

If it is to be assumed that all teacher education programs are providing insights into best practice, why do there continue to be a large number of teachers who teach in ways that do not reflect current reform efforts and suggestions for "best practice"?

One explanation may be that teacher beliefs are deeply entrenched and difficult to change (Kagan, 1992). Beliefs are conceptions held by a person that are believed to be true (Richardson,

1996). Numerous studies within the past ten years have identified the beliefs about teaching and learning held by preservice and inservice teachers (summarized in Kagan, 1992). Beliefs, more than content knowledge, are the best indicators of predicting classroom practice (Gess-Newsome, 1999; Pajares, 1992). For example, two teachers may have similar knowledge about mathematics but will teach in two different ways (Ernest, 1989). Ernest suggests that "the powerful effect of beliefs is more useful in understanding and predicting how teachers make decisions" (Ernest, 1989). Beliefs may be the best way in which to predict what teachers will do in the classroom, but verbalization of best practice does not guarantee that teachers will do as they say. One of the key findings of the Salish I Research Project (1997a) was that first year teachers were able to talk about best practices, but classroom observations revealed that they were teaching in traditional, teacher-centered ways.

To follow the development of beliefs, research on the beliefs of preservice teachers is essential. By identifying the beliefs towards teaching and learning held by teacher candidates, it is proposed that steps can be taken to encourage a change in beliefs. This identification of beliefs would in turn lead to changes in teaching practices that are congruent with the current reform movement (Prawat, 1992).

New teachers do not begin their careers without attitudes and beliefs about the profession. Before starting teacher education programs, preservice teachers have firmly grounded beliefs towards students, learning, classrooms, and the subject matter to be taught (Kagan, 1992). Beliefs held prior to a program are resistant to change and education students leave programs with the same beliefs they had when they started the program (Shaw & Cronin-Jones, 1989).

Other key studies involving the beliefs of preservice teachers involved constraints that prohibited a more complete analysis of how teachers described their ideas towards teaching and learning. These constraints included: low number of volunteers, with most studies including

twelve or fewer participants (Kagan, 1992); no associated teaching practicum during the methods course (Lederman, Gess-Newsome, & Latz, 1994); a single methods course within a two year program (Shaw & Cronin-Jones, 1989); or limited data collection, which was often restricted to written self-report instruments (Hashweh, 1996). Not a single study has been completed in the absence of these constraints. This study was designed to survey a greater number of participants and included observations of the teacher candidates in the classroom. Also, this study was completed to provide additional information regarding preservice teacher beliefs and how these beliefs translate into classroom practice.

The unique components of the secondary teacher education program at the large, Midwestern university used in this study may provide greater insight into preservice teachers beliefs in the absence of the above listed constraints. The two year program provides a field teaching component within each of the three sequential methods courses. The methods courses are designed to build knowledge from each of the previous courses, not dispense arbitrary information that the student is expected to retain and use in his or her actual teaching. The students in the program complete each course as a cohort group. A cohort is a group of students who proceed together through each of the three methods courses and associated practica.

The purpose of this study is to identify patterns in the belief systems held by secondary science preservice teachers within and between each cohort and to compare beliefs held to actual classroom practice. It was the expectation that this study would identify patterns of congruency between beliefs and practices as students gain more experience and knowledge while they proceed through the three semester methods sequence.

The identification of the beliefs held by secondary science preservice teachers through three semesters of study and practice in science teaching is of prime interest in this study. Knowledge of these beliefs and how these beliefs are incorporated into classroom practice may

provide useful information for instructors responsible for preservice programs and thus lead to a more streamlined program that is oriented towards improving classroom practice by reflecting and challenging beliefs. More precisely, neglecting to identify the beliefs of preservice teachers "may be responsible for the perpetuation of antiquated and ineffectual teaching practices" (Pajares, 1992, p. 328).

Constructivist based classrooms begin with assessing student's prior knowledge on a given subject. In a similar manner, identification of these conceptions should be the first step in aligning beliefs with best teaching practices. Studying beliefs and practices over the course of a preparatory program is especially important. Too often the focus of best practice in institutions is confined to experience in a single one semester methods course prior to student teaching.

With the inclusion of three methods courses in a secondary science teacher preparation program, preservice teachers should have more opportunities to reflect on science as a content area, teaching practices, and beliefs about teaching and learning. Assessing congruency of beliefs with practice over three semesters prior to student teaching should identify areas in which preservice teachers are able to implement theory into desired practice. The converse is also important: incongruencies between stated beliefs and practice will help identify areas of difficulty in incorporating pedagogy into practice. Identifying the areas of difficulty may help instructors develop modifications designed to change beliefs to align with best practice within their teacher education programs that could help better prepare students for the demands they will face during student teaching and their careers beyond the collegiate experience.

Methodology and Research Design

The focus of this study was to identify beliefs about teaching and learning held by students in a secondary science teacher education program. The research design was exploratory

in nature: that is, there were no preconceived hypotheses of the researcher to be validated. Quantitative methodologies were used to identify patterns of beliefs of secondary science preservice teachers and to describe relationships between these beliefs and actual classroom practices. To insure the representation of all participants in the study (*n*=42), quantitative methods were used to identify patterns instead of selecting a small number of volunteers to participate in a case-study.

Multivariate procedures were used to control for intercorrelations within the instruments to provide a clearer representation of patterns than could be described by qualitative procedures. The statistical analyses identified patterns that warranted further investigation. Beliefs and practices were examined across the domains of Teacher and Content, Teacher Actions, and Student Actions (Salish I Research Project, 1997b). An additional category of Philosophy of Teaching was included since it provided valuable insights concerning beliefs that are not included in the other domains.

The research questions that provided the focus of this study were:

1. What patterns can be identified in the beliefs of secondary science preservice teachers within each of the three science methods ?

2. What patterns can be identified in the beliefs of secondary science preservice teachers between the three science methods cohorts ?

3. What patterns emerge within each cohort and between the three cohorts of secondary science preservice teachers regarding beliefs towards constructivist practice?

4. What patterns can be identified within each cohort and between the three cohorts of secondary science preservice teachers in classroom practices?

5. How congruent are pedagogical beliefs of secondary science preservice teachers with classroom practice?

Three kinds of data were collected. The first instrument, the Constructivist Learning Environment Survey, CLES, (Taylor, Fraser & White, 1994), is a Likert scale instrument designed to assess the degree to which constructivist strategies are included in the classroom.

The second data source, the Teachers Pedagogical Philosophy Interview, TPPI, (Richardson & Simmons, 1994, 1997) consists of over 50 open-ended questions designed to identify pedagogical beliefs. Fifteen of the questions were selected for use in this study in the areas of teacher actions, student actions, content knowledge, and philosophy of teaching and learning.

The third data source, the classroom observation rubric of the Expert Science Teaching Educational Evaluation Model, ESTEEM, (Burry-Stock & Oxford, 1993) is designed to measure constructivist teaching practices via classroom observations. The TPPI and ESTEEM were selected based on the interrelationships across the domains of Teacher Actions, Student Actions, and Teacher and Content. Both instruments contain subscales that are closely related.

The Teacher and Content domain represents the preservice teachers understanding of the nature of science, relevance of science to the world outside of school, and the ability to use appropriate and accurate examples and explanations of science content.

The Teacher Actions domain relates to how the teacher perceives his or her role in the classroom. This includes decisions regarding selection and modification of instructional strategies, curricular choices, student assessments, questioning skills, and classroom interactions between teacher and students.

The Student Actions domain regards how the teacher facilitates student understanding by monitoring student behaviors, learning activities, and discussions. This also includes the preservice teachers beliefs regarding the nature of learning.

Participants in this study included students enrolled in the three secondary science methods courses at a large Midwestern university: Science Methods I: Introduction to Science Teaching, Science Methods II: Research Based Framework for Teaching Science, and Science Methods III.

Data Analysis and Interpretation

The research questions, statistical analysis, and the interpretation of the data are presented.

Research Question 1

What patterns can be identified in the beliefs of secondary science preservice teachers within each of the three science methods cohorts?

To address this question, the results of the TPPI were the main data source. The TPPI responses were categorized along a continuum of "teacher directed" (score of 1) to "student-centered" (score of 5) for each of the questions. A score of 2 indicates a transitional constructivist response: some responses or parts of responses on an item would define a teacher-centered orientation, while including some indications of student-centered ideas. A score of 3 indicates a conceptual understanding of constructivist strategies and responses are best described as demonstrating an emerging understanding of constructivist practices. A score of 4 is defined as an early constructivist, indicating an understanding that is mostly, but not completely, student-centered practice. This scoring method was utilized in previous studies (Salish I Research Project, 1997a; Craven, 1997; Tillotson, 1996). The coding was completed using the rubric provided by Craven and expanded using the original scoring categories developed by the authors of the TPPI (Richardson & Simmons, 1994).

SPSS version 9.0 was used for the statistical analyses for this research question. Descriptive statistics for each of the subscales of the TPPI were computed. The subscale scores

on the TPPI were analyzed using Cluster Analysis (Sharma, 1996). Because the identification of patterns within each cluster is more exploratory than theoretical in nature, hierarchical cluster analysis was first performed to identify the optimal number of clusters before conducting a non-hierarchical cluster analysis (Koehly, in press). Cluster analysis was used because it determines homogeneous groups within each Methods cohort. An initial hierarchical clustering using Ward's method with a squared Euclidean distance was completed to determine an optimal number of clusters within each group. Ward's method was used because "it forms clusters by maximizing within-clusters homogeneity" (Sharma, 1996, p. 193). That is, it forms groups by determining clusters that have the least amount of within group variability.

After the optimal number of clusters was determined, a K-means cluster analysis was completed to identify which combinations of subscales discriminated between clusters. This analysis computed subscale cluster centers for each Methods cohort. The cluster centers were then compared to the overall cohort mean on each subscale to identify patterns within each cohort.

Methods 1 Cohort Patterns

Table 1

Cluster Centers of the TPPI Subscales for Methods 1 Cohort

	Cluster				
Subscale	1	2	3	4	Mean
Teacher/Content	3.25	1.50	1.50	2.33	2.10
Teacher Actions	3.17	2.50	3.33	2.00	2.57
Student Actions	2.90	2.35	2.60	3.53	2.84
Teaching Philosophy	3.00	2.00	4.25	2.25	2.50
n per cluster	2	4	1	3	

Methods 1 overall means corresponded to transitional beliefs of constructivist teaching practice. The cluster with scores above the mean showed a conceptual understanding. One cluster had a pattern that included a mixture of early constructivist and didactic responses.

Main themes within Methods 1 cohort included:

1. Evidence of student learning was demonstrated by the students explaining concepts to the teacher or peers.

2. The use of activities was important to promote student understanding and enthusiasm towards the learning of science.

3. Lesson planning will be determined by mandated school curriculum.

4. Students should view science as fun and doable.

5. The best teaching and learning experience was described as a traditional lecture and laboratory model.

A majority of the students (8 out of 10) had difficulty responding to questions regarding the nature of science. As with a former study conducted by Aguirre, Haggerty and Linder (1990), the question "what is science?" confused many students. Their study included 74 preservice teachers who were asked this question. Forty percent of the participants responded with naive views concerning the nature of science. Responses received during this study were often brief. The difficulty faced by many students within all cohorts indicated a lack of experience in reflecting on the content they teach. The lack of understanding of the processes involved in science was demonstrated in what science concepts they viewed as important for students to know. The same 8 students responded by listing broad topics (i.e., genetics, human disease, ecology) indicating a traditional view of important science concepts. The other two students reported a conceptual view by the inclusion of the importance of citizenship skills.

A naive constructivist view was evident in the majority of students responding that activities will be the main strategy in manipulating the learning environment. Naive constructivism is a faith that learning will occur if children are active (Prawat, 1992). Students actively engaged in activities do not necessarily develop conceptual understanding (Nelson & Moscovici, 1998).

Methods 2 Cohort Patterns

For the Methods 2 cohort, the same procedure was followed. From the hierarchical cluster analysis, it was determined that 4 clusters was the optimal number of groups. The results of the cluster analysis are presented in Table 2.

Cluster 1 is above the mean on Teacher and Content and below the mean on the other subscales, this group scored in the transitional/conceptual range. Cluster 2 has the highest subscale score of any of the clusters for Teacher Actions (in between early constructivist and student-centered scores) and had scores in the transitional range on the other subscales. Cluster 3 followed the mean subscale scores closely with conceptual scores. Subscale scores for Cluster 4 were consistently above the mean; three subscales indicate early constructivist responses.

Table 2

Cluster Centers of the TPPI Subscales for Methods 2 Cohort

	Cluster				
Subscale	1	2	3	4	Mean
Teacher/Content	3.13	2.50	2.71	4.00	3.00
Teacher Actions	2.50	4.67	3.11	4.00	3.30
Student Actions	2.30	2.40	3.50	4.30	3.33
Teaching Philosophy	3.25	2.75	3.13	3.25	3.14
n per cluster	2	1	6	2	

The Methods 2 cohort average responses represented an overall conceptual understanding of constructivist practices. One cluster exhibited a pattern representing transitional and conceptual understanding. The cluster with the highest means demonstrated a pattern of early constructivist and conceptual understanding.

Main themes within the Methods 2 cohort included:

1. Student learning is demonstrated by the student explaining concepts to other students. The ability to apply new information to previous knowledge would also demonstrate learning.

2. The decision on what will be taught was based on the inclusion of a variety of activities within the guidelines of mandated curriculum.

3. Critical thinking skills were perceived to be the most valuable learning.

4. Science is viewed as an attempt to understand the natural world.

Questions regarding the nature of science were answered in a similar manner by all students: science is trying to understand the natural world and is based on the principle that the natural world can be understood, representing a "transmission" view of science, that observations will lead to scientific knowledge (Aguirre, Haggerty and Linder, 1990).

The two students with an early constructivist understanding included the themes of student relevance in guiding instruction since this was considered to be the most valuable learning. The role of human bias in how scientific knowledge is constructed was another broad theme that was also considered to be the most important science concept. Non-traditional learning situations were described in which students had the autonomy to design and carry out their own experiments as the best learning situation experienced by the two students; however, these ideas did not carry over into decisions regarding how they will teach.

Methods 3 Cohort Patterns

The identification of clusters within the Methods 3 cohort followed the same procedure as with the other two cohorts. It was determined by hierarchical cluster analysis that 4 clusters were optimal.

Table 3

Cluster Centers of the TPPI Subscales for Methods 3 Cohort

Subscales	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Mean
Teacher/Content	2.50	1.50	3.07	3.42	2.98
Teacher Actions	2.33	2.33	3.14	4.33	3.31
Student Actions	2.80	2.40	3.51	2.80	3.18
Philosophy Teaching	4.25	2.75	2.93	3.75	3.23
n per cluster	1	1	7	3	

From the above table, it can be seen that Cluster 1 consists of an outlier who had the highest score on the Philosophy of Teaching and Learning of all the clusters, and was below the mean on the other three subscales. Cluster 2 consists of an outlier who was below the mean on all subscales. Cluster 3, the largest group, was above the mean on Teacher and Content and Student Actions, and below the mean on Teacher Actions and Philosophy of Teaching and Learning. Cluster 4 was above the mean on all subscales except for Student Actions. No cluster was consistently above the mean on all subscales.

The Methods 3 cohort responses overall represented a conceptual understanding of constructivist practices. One cluster included a mixture of transitional and early constructivist understanding. The cluster consistently below the mean represented responses of didactic and transitional understanding of constructivist practice.

The predominant trends within this cohort include:

1. The purpose of science is to understand the natural world, the natural world can be explained, and science is a worthwhile endeavor.

2. Teachers will select pieces of the required curriculum that is of the most interest to them.

3. Process skills, including critical thinking, will be the most valuable learning outside the classroom.

4. Teachers will know that learning is occurring when students are able to explain a concept to the teacher or peers.

The emergence of early constructivist understanding included responses regarding the classroom environment established by the teacher. An intellectually safe, risk-taking environment was important to the students within this cluster. In this environment, students would feel safe to explore science concepts in a variety of ways, capitalizing on cooperative groups as the dominant strategy in which students would learn. Student interest and relevance would be the most important factor in determining the curriculum.

Overall, distinct patterns representative of all students within a cohort were difficult to define. All possible combinations of high and low subscales were represented. As reported in a previous study, no "typical" pattern of beliefs of a preservice science teacher emerged (Shaw & Cronin-Jones, 1989).

Research Question 2

What patterns can be identified in the beliefs of secondary science preservice teachers between the three science methods?

Differences between each cohort were determined using a multivariate analysis of variance (MANOVA) of the TPPI subscales using SPSS version 9.0. Multivariate analysis of

variance allows for the analysis of several categorical independent variables with continuous dependent variables (Sharma, 1996). A multivariate analysis was preferred because of the relatively low sample size of each cohort. MANOVA takes into account intercorrelations between subscales, thereby controlling for overall experiment-wise error. Further, it allows for a simultaneous analysis of cohorts with each subscale instead of several separate one-way analysis of variance procedures. A least significant difference follow-up procedure was used to locate the subscale differences between the cohorts.

A multivariate analysis of variance was completed using each subscale of the TPPI as the dependent variables and the methods cohort as the independent variable. This procedure was designed to determine if there were statistically significant differences between the groups across all subscales simultaneously. Box's test for assumptions of equality of covariance matrices (significance of 0.987) was completed with satisfactory results that indicated the assumption for the MANOVA test had been met.

Tests of Between-Subjects Effects indicated that there are significant differences between the methods cohorts on the TPPI subscales. Wilks' Lambda was computed to be 0.625 (significance of 0.099) with an eta squared based on the Wilks' Lambda to be 0.210. The alpha level of 0.10 was selected because of the exploratory nature of the research question.

A post-hoc least significant difference procedure was used to determine the location of significant differences. The post hoc procedure between the cohorts indicates that Methods 1 Cohort is significantly different from Methods 2 and 3 on the subscales of Teacher/Content and Teacher Actions. Methods 1 is significantly different from Methods 3 on the Philosophy of Teaching Subscale. Methods 2 and 3 are not significantly different on any of the subscales. The results of the post hoc tests are in Table 4. Significant differences at the $\alpha=0.10$ are marked with an asterisk.

The results indicated that the Methods 3 cohort and the Methods 2 cohort each had significantly higher scores than the Methods 1 cohort on the subscales of Teacher/Content, Teacher Actions, Philosophy of Teaching and Learning. Potential factors that may have contributed to these differences were the instructor differences, the grade level taught during the practicum, and a greater number of classroom experiences.

Table 4

Multiple Comparisons of TPPI Responses for Three Methods Cohorts

Subscale	Methods	Methods	Mean Difference	Std. Error	Sig.
TC	1	2	-0.6270*	0.2944	0.041
		3	-0.5878*	0.2885	0.050
	2	1	0.6270*	0.2944	0.041
		3	3.917E-02	0.2812	0.890
TA	1	2	-0.6037*	0.2922	0.048
		3	-0.6062*	0.2863	0.043
	2	1	0.6037*	0.2922	0.048
		3	-2.525E-03	0.2791	0.993
SA	1	2	-0.4223	0.2884	0.154
		3	-0.2783	0.2826	0.333
	2	1	0.4223	0.2884	0.154
		3	0.1439	0.2755	0.605
PTL	1	2	-0.4454	0.2758	0.117
		3	-0.5382*	0.2702	0.056
	2	1	0.4454	0.2758	0.117
		3	-9.280E-02	0.2635	0.727

Note: * indicates significance at the 0.10 alpha level

A review of responses across the subscales identified student-centered ideas that were reported by Methods 2 and Methods 3 students that were not reported by Methods 1

students. The lower mean on the Teacher and Content subscale for the Methods 1 cohort can be attributed to the responses received, especially the two questions: "What are the founding principles of science?" and "What science concepts do you believe are the most important for you students to understand by the end of the school year?" Most Methods 1 students would like their students to view science as fun, anybody can do it, interesting, and worthwhile. For the Methods 2 and Methods 3 cohort, the higher subscale mean was due to students answering all of the questions more completely than the Methods 1 students. Responses for how they would like their students to view science included the Methods 1 responses with the addition of science as a human endeavor, subject to biases and limitations of human nature.

The higher subscale mean for the Teacher Actions subscale showed a progression through teacher-centered ideas to student-centered ideas for deciding when to move from one concept to the next. For Methods 1 cohort, the most frequent responses included the teacher connecting new information to prior lessons. Three students indicated the didactic "following a schedule" and testing. The single person in Cluster 3 indicated she would move on when students understand a concept.

For the Methods 2 cohort, the majority of students stated they would move on to a new concept when their students understand. Two students would follow a schedule and would make connections between the concepts. All students in the Methods 3 cohort indicated they would move to a new concept when student understanding and the goals for the unit have been reached.

Methods 1 students indicated they would provide many activities in order to manipulate the learning environment to maximize student understanding, indicating a conceptual constructivist perspective. For Methods 2 students, activities were important for a majority of the students. Three students described the non-threatening, caring environment they would establish in which students felt safe expressing their ideas. A safe intellectual environment was

important for a majority of the Methods 3 students, indicative of an early constructivist perspective.

The Philosophy of Teaching and Learning subscale responses between the cohorts also showed a progression through traditional science teaching ideas to constructivist ideas. A majority of Methods 1 students thought the most valuable learning outside of the classroom environment was the knowledge of basic science concepts. Methods 2 students indicated that process and critical thinking skills were most important. Citizenship, working with others and critical thinking skills were the reported most frequently for Methods 3.

The best teaching and learning situation was described by most Methods 1 students in which they were the student in a traditional lecture and lab setting. Two Methods 2 students also described scenarios in which they were students experiencing a good lecture. The majority described a situation in which they were responsible for designing their own experiments. A majority of Methods 3 students described a class they had taught that included problem solving and lab activities.

Similarities existed in responses across the cohorts for the description of a good learner: a good listener, asks questions, internally motivated, and open-minded.

The statistically non-significant difference on the Student Actions subscale between the cohorts reflected the responses received. This subscale was concerned with how the teacher will know when learning is occurring and how students learn science best. All cohorts had a combination of teacher-directed responses and student-centered responses. Students in all three cohorts included a range of responses regarding how their students learn science best, from "the same way I do" to "all students learn differently." The most frequent response for determining when a student has learned a concept across all cohorts was "when the student can explain it others."

Research Question 3

What patterns emerge within each cohort and between the three cohorts of secondary science preservice teachers regarding constructivist practice?

The results of the CLES were analyzed using SPSS version 9.0 to answer this question. Descriptive statistics were computed. Averages of the subscales were used to provide continuity on a 1 to 5 scale among the TPPI, CLES and ESTEEM in comparing results of the three instruments. As with the TPPI, the CLES subscale scores, a 5 represents "student-centered" and a score of 1 represents "teacher-centered".

To identify within group patterns, cluster analysis was conducted in the same manner as with Research Question 1. The cluster analysis determines similar groups within each of the Methods cohorts. The cluster centers of each of the subscale scores were compared to the mean to identify patterns within each cohort.

To determine if between cohort differences existed on the CLES, a multivariate analysis of variance procedure was conducted in the same manner as Research Question 2. This procedure determines if differences exist between the cohorts on each subscale. The least significant difference follow-up test was conducted to locate the between cohort differences.

To identify patterns in scores obtained on the CLES for each cohort, a hierarchical cluster analysis using Ward's method was conducted. The results determined the optimal number of clusters to use for the K-means Cluster Analysis. Scores ranged from a possible 5 points which indicated a student-centered response, and a 1 which indicated a more teacher-centered response.

Methods 1 CLES Clusters

The means of the clusters for the CLES for the Methods 1 cohort are presented in Table 5. The clusters on the CLES for the Methods 1 cohort indicated that Clusters 1, 2 and 3 had similar patterns: the highest subscales within the clusters were Personal Relevance, Critical

Voice, and Student Negotiation. The lowest subscale scores were for Scientific Uncertainty and Shared Control. Cluster 1, an outlier, showed this pattern except for the Student Negotiation subscale, which was the lowest cluster center for this subscale.

Table 5

Cluster Analysis Results for the CLES for Methods 1 Cohort

Subscale	Cluster				Mean
	1	2	3	4	
PR	4.29	3.36	4.08	3.14	3.80
SU	1.86	2.57	3.02	2.86	2.78
CV	4.14	3.25	3.53	4.00	3.53
SC	2.00	2.00	2.80	2.29	2.45
SN	4.00	3.64	3.73	2.43	3.63
AT	4.43	3.50	3.90	3.43	3.78
n for cluster	1	4	7	1	

Methods 2 CLES Clusters

Hierarchical cluster analysis followed by the K-means cluster analysis indicated that two clusters were optimal for the Methods 2 cohort on the CLES.

The cluster analysis results showed that Cluster 1 was consistently above the mean while Cluster 2 was consistently below the mean. The two clusters were nearly parallel to each other and to the mean. It was interesting to note that the two lowest subscales (Scientific Uncertainty and Shared Control) were the same low subscales for the Methods 1 cohort.

Table 6

Cluster Analysis Results for CLES for Methods 2 Cohort

Subscale	Cluster 1	2	Mean
PR	4.10	3.32	3.86
SU	3.17	2.36	2.92
CV	4.05	3.32	3.82
SC	3.35	2.07	2.96
SN	4.21	3.25	3.91
AT	3.92	3.04	3.65
n for cluster	9	4	

Methods 3 CLES Clusters

Hierarchical and K-means cluster analysis results indicated that three clusters were optimal for the Methods 3 cohort on the CLES. Cluster 1 was consistently above the mean on each subscale. Cluster 2 was consistently below the mean on each subscale. Cluster 2 was above the mean for the Scientific Uncertainty subscale and at or below the mean for the other subscales.

The general pattern that was evident for Methods 1 and Methods 2 cohorts is also evident for Methods 3, that the lowest subscales were Scientific Uncertainty and Shared Control. The subscales of Personal Relevance, Critical Voice and Student Negotiations provided the highest subscale scores across each of the Methods cohorts.

Table 7

Cluster Analysis Results for the CLES for Methods 3 Cohort

Subscale	Cluster			Mean
	1	2	3	
PR	3.81	3.71	3.55	3.69
SU	3.64	2.68	3.12	3.21
CV	4.29	4.04	3.86	4.06
SC	3.12	2.04	2.71	2.70
SN	4.36	4.14	3.50	3.98
AT	3.71	3.43	3.43	3.56
n for cluster	6	4	6	

Between Cohort Differences on the CLES

To test if the scores obtained on the CLES between the cohorts were statistically significantly different, a multivariate analysis of variance was conducted. The assumption of the equality of covariance matrices was satisfied as indicated by a Box's statistic of 0.758. The Wilk's Lambda of 0.464 (significance of 0.006) indicated differences existed between the cohorts on the CLES. An eta square of 0.319 was calculated based on the Wilk's Lambda that indicated a moderate effect size.

To locate the source of the differences, a least significant difference follow-up procedure was conducted. Locations of significant differences (α=0.10) are marked with an asterisk on Table 8. No significant difference between the cohorts was found for the subscales of Personal Relevance and Attitude. Significant differences between cohorts include scores for Methods 3 are higher than scores for Methods 1 on the subscales of Scientific Uncertainty, Critical Voice and Student Negotiations. Methods 2 scores are higher than Methods 1 on the subscales of

Critical Voice and Shared Control. Methods 3 is not higher than Methods 2 for any of the subscales.

The scores of the Methods 1 students were not truly their own perceptions of how well their classrooms measure constructivist practice. The students responded according to the classroom they were observing and assisting. The results should be interpreted as their perceptions of the learning environment established by the cooperating teachers. In this context, methods students did not think that elemenatary students should question teacher's pedagogical decisions. They also believed that students should not be able to complain about activities, decide how they would be assessed, or decide what they would learn.

Areas of strengths, reflecting conceptual/early constructivist understandings included: science is portrayed as being important outside of school, students should work together in solving problems, students should share their ideas and results with each other, and students generally enjoy science instruction.

Ideas related to the nature of science were not as strong. The overall trend indicated a conceptual understanding of science as a human endeavor, influenced by values and opinions. These ideas expressed on the CLES, a Likert scale instrument, were not supported by the open-ended responses on the TPPI.

Methods 2 students completed the survey responding according to observations of their cooperating teachers' classrooms. The general trends were similar to those of Methods 1 students. Strengths included the importance of science to the world outside of school, cooperative group work and sharing of ideas, and students enjoying science class. An additional strength emerged as students felt they were allowed to question the value of the learning activities.

Table 8

Multiple Comparisons of CLES Scores for the Three Methods Cohorts

Subscale	Methods	Methods	Mean Difference	Std. Error	Sig.
PR	1	2	-0.3846	1.2648	0.763
		3	0.8029	1.2040	0.509
	2	1	0.846	1.2648	0.763
		3	1.1875	1.2040	0.330
SU	1	2	-1.0000	1.3965	0.478
		3	-2.9760*	1.3295	0.031
	2	1	1.0000	1.3965	0.478
		3	-1.9760	1.3295	0.145
CV	1	2	-2.0769*	1.1253	0.073
		3	-3.7452*	1.0713	0.001
	2	1	2.0769*	1.1253	0.073
		3	-1.6683	1.0713	0.127
SC	1	2	-3.5385*	1.7203	0.046
		3	-1.7212	1.6377	0.300
	2	1	3.5385*	1.7203	0.046
		3	1.8173	1.6377	0.274
SN	1	2	-2.0000	1.5177	0.195
		3	-2.4904*	1.4448	0.093
	2	1	2.0000	1.5177	0.195
		3	-0.4904	1.4448	0.736
AT	1	2	0.9231	1.2490	0.464
		3	1.7115	1.1890	0.158
	2	1	-0.9231	1.2490	0.464
		3	0.7885	1.1890	0.511

Note: * indicates significance at alpha=0.10

Areas that included a transitional/conceptual understanding were science as a human endeavor and the shared planning of class activities by the teacher and the student. The ideas relating to student involvement in the management of the class indicated a more constructivist environment than for the Methods 1 cohort, but remained a relative weakness for the Methods 2 cohort.

Methods 3 students completed the survey entirely with respect to their own views of how they established the learning environment during the practicum. The overall, general trends were the same as for Methods 1 and Methods 2, although higher than Methods 1 regarding the relevance of science outside of the classroom, the degree to which cooperative learning was utilized, and the expression of student opinions with regards to the purpose of the learning activities. Methods 3 students represented an early constructivist understanding in these areas. Science as a human endeavor was a relative weakness of the Methods 3 cohort, although above the Methods 1 cohort mean. The ideas relating to the shared planning and decision making of students and teachers was also a weakness for Methods 3 students.

Because this instrument was designed to identify the degree to which constructivist practices are perceived to occur in classrooms, this instrument uncovered areas of strengths and weaknesses. For each cohort, the overall trends were similar. Personal relevance, student negotiation, and critical voice were all relatively strong within and between each cohort. Shared control and scientific uncertainty were the lowest subscale scores of each cohort. In past studies, the low scores on these subscales were also reported (Taylor, Dawson, & Fraser, 1995; Taylor, Fraser, & White, 1994).

Research Question 4

What patterns of classroom practice can be identified within each cohort and between the three cohorts of secondary science preservice teachers?

SPSS version 9.0 was used to complete the analyses for this research question. Descriptive statistics within each subscale of the ESTEEM for each methods cohort were computed. To determine within cohort patterns of classroom practice, a hierarchical cluster analysis followed by a K-means cluster analysis was completed in a similar manner as Research Question 1. Subscale cluster centers were compared to the mean subscale scores for the entire cluster to identify patterns within each cohort.

Between cohort patterns were identified by conducting a multivariate analysis of variance with each subscale of the ESTEEM with the three methods cohorts. The location of the between group differences was determined using a least significant difference follow up procedure. For each Methods cohort, the Ward's hierarchical cluster analysis followed by a K-means cluster analysis indicated that 3 clusters were optimal.

Methods 1 Results on ESTEEM

For the Methods 1 cohort, the cluster analysis resulted in a cluster that was consistently higher than the mean across all subscales (Cluster 3). Cluster 1 was above the mean for Facilitating Learning and below the mean for the other subscales. Cluster 2 was below the mean for all subscales.

All students within this cohort were required to teach an inquiry based activity with the elementary students. Most students (six out of nine) demonstrated student-centered practices.

Three patterns were identified regarding classroom practice. The largest group was identified as exhibiting early constructivist/constructivist teaching. The students in this group were exceptionally knowledgeable concerning science, were able to engage students in discussions and activities, and varied the teaching methods according to interactions with students.

Table 9

Cluster Centers on ESTEEM for Methods 1 Cohort

Subscale	Cluster			Mean
	1	2	3	
Facilitating Learning	3.90	2.60	4.43	3.88
Content Pedagogy	3.67	2.72	4.33	3.82
Context Pedagogy	3.50	3.11	4.19	3.81
Content Knowledge	3.17	3.55	4.76	4.19
n per cluster	2	3	7	

The second largest group consisted of students who were knowledgeable about science, but demonstrated a transitional/conceptual understanding of pedagogical decisions. This group showed the ability to monitor student understanding and adjust instruction accordingly, but were not as able to engage students in learning activities or use higher order thinking skills.

The third group showed conceptual/early constructivist practices concerning pedagogical decisions but was weaker in content knowledge. These students were able to involve the students physically and mentally, show the relevance of the science concepts, and adjust teaching strategies according to students' understanding.

Methods 2 Results on ESTEEM

The cluster analysis for Methods 2 cohort revealed that no cohort is consistently above or below the mean across all of the subscales. These results showed that Cluster 1 was above the mean for Facilitating Learning and below the mean for the other subscales. Cluster 2 was below the mean for Facilitating Learning and above the mean for the other subscales. Cluster 3 was above the mean for Facilitating Learning and Content Pedagogy and below the mean for the other two subscales.

Table 10

Cluster Centers on ESTEEM for Methods 2 Cohort

Subscale	Cluster			Mean
	1	2	3	
Facilitating Learning	3.60	3.47	4.00	3.56
Content Pedagogy	3.42	3.78	3.83	3.70
Context Pedagogy	2.17	3.89	3.33	3.44
Content Knowledge	3.25	3.79	2.75	3.56
n per cluster	2	6	1	

For the Methods 2 cohort, two patterns were the most prominent. The largest group demonstrated conceptual/early constructivist teaching concerning content knowledge, choosing a variety of teaching methods that relate to conceptual understanding, and ability to modify instruction based on student behaviors. However, the teachers, more than the students, guided the learning.

The second pattern included students that showed conceptual understanding of content knowledge and classroom practice in the areas of facilitating learning and planning a variety of activities. However, when they were faced with these activities not helping students gain conceptual understanding of concepts (in this case, phases of the moon), they were unsure of how to modify instruction. After speaking with the students to understand their perceptions of the practicum, they explained they planned activities certain that students would grasp the difficult concepts involved with understanding the phases of the moon. They felt well prepared to teach students. However, when the middle school students did not respond as anticipated, the practicum students did not anticipate student confusion and did not provide other plans or know

how to modify instruction. This provided an example of the "overly optimistic" preservice teacher described by Pajares (1992).

Methods 3 Results for ESTEEM

Cluster analysis for the Methods 3 cohort on the ESTEEM indicated that Cluster 1 was consistently above the mean on each of the subscales, Cluster 3 was consistently below the mean on all subscales. Cluster 2, the largest group was at or below the mean on each of the subscales, and this group most closely resembled the mean pattern.

Two patterns were prominent in the Methods 3 cohort regarding classroom practice. The larger group consisted of students who displayed a conceptual understanding of engaging students in the activities and using higher order thinking skills to promote student understanding. The strongest areas for this group were the ability to modify instruction based on what students were doing and saying. The students contributed this ability to having greater experiences on a daily basis, which supported the research of Richardson (1996).

Table 11

Cluster Centers on ESTEEM for Methods 3 Cohort

Subscale	Cluster 1	Cluster 2	Cluster 3	Mean
Facilitating Learning	4.33	3.00	2.60	3.36
Content Pedagogy	4.04	3.06	3.00	3.35
Context Pedagogy	4.20	3.61	2.00	3.63
Content Knowledge	4.32	3.54	2.50	3.67
n per cluster	3	6	1	

The second group consisted of students who displayed an early constructivist understanding of classroom practice in all areas observed. These students were able to: engage

students actively in learning, use a variety methods and adjust methods based on student understanding, use higher order thinking strategies, identify student misperceptions, and integrate concepts and skills.

Between Cohort Results for ESTEEM

To test if the subscale scores of the ESTEEM were different between each of the cohorts, a multivariate analysis of variance procedure was conducted. The results indicate that no significant differences exist between the three cohorts regarding classroom practices. (Wilk's Lambda= 0.227, eta squared calculated 0.188). The observed power (0.69) indicated that the low sample size may be the reason for not obtaining significant differences. Box's test for equality of covariance matrices indicated significant results ($p < 0.001$). In this case, the assumption of equality of covariance matrices was not satisfied.

The results indicated that the significant differences were between Methods 1 and Methods 3 for the subscales of Facilitating the Learning Environment, Content Specific Pedagogy, and Content Knowledge. For each of these subscales, Methods 1 scores were higher than Methods 3 scores. Methods 1 scores were higher for Methods 2 scores for the Content Knowledge subscale. These results cannot be accurately interpreted since Methods 1 cohort was observed by a different researcher than Methods 2 and 3 cohorts. No differences were located between Methods 2 and Methods 3.

Table 12

Multiple Comparisons of the ESTEEM Scores for the Three Methods Cohorts

Subscale	Methods	Methods	Mean Difference	Std. Error	Sig.
EST 1	1	2	0.3278	0.3397	0.343
		3	0.6167*	0.3397	0.081
	2	1	-0.3278	0.3397	0.343
		3	0.2889	0.3631	0.433
EST 2	1	2	0.1157	0.2641	0.665
		3	0.5787*	0.2641	0.037
	2	1	-0.1157	0.2641	0.665
		3	0.4630	0.2823	0.113
EST 3	1	2	0.3611	0.3035	0.245
		3	0.2870	0.3035	0.353
	2	1	-0.3611	0.3035	0.245
		3	-7.4074E-02	0.3245	0.821
EST 4	1	2	0.6353*	0.3096	0.050
		3	0.5797*	0.3096	0.072
	2	1	-0.6353*	0.3096	0.050
		3	-5.5556E-02	0.3310	0.868

Research Question 5

How congruent are pedagogical beliefs of secondary science preservice teachers with classroom practice?

SPSS version 9.0 was used for the first analysis of this research question. The total number of participants was used for an overall analysis instead of individual cohort analyses since it was not expected that the relationship between beliefs and practice would be due to

cohort differences. The results of the TPPI were compared to the results of the ESTEEM using Pearson's Product moment correlation technique.

To further understand the association between the TPPI and ESTEEM, a canonical correlation was computed using SAS version 6.12a (1996). The canonical correlation determined the best linear combination of the two sets of variables that maximized the association between the two instruments. The computation involved the creation of a composite score for the TPPI and a composite score for the ESTEEM. Linear combinations of each set of variables were computed that described the maximum possible association of the composite scores. By computing the canonical correlation betweeen the TPPI and the ESTEEM, the linear combination of the subscales was calculated to describe the maximum association possible between the subscales of the two instruments.

To explore the relationship between beliefs of preservice teachers with classroom practice, Pearson's Product Moment correlations were computed using the subscales of the TPPI with the ESTEEM subscales. The results are reported in Table 13. A total of twenty-seven students completed both instruments. No significant correlations at the 0.05 alpha level were found. Inspection of the scatterplots did not indicate a non-linear association.

Table 13

Linear Correlations Between TPPI Subscales and ESTEEM Subscales

	EST 1	EST 2	EST 3	EST 4
TC	-0.027	0.033	-0.044	-0.163
TA	-0.262	-0.291	0.177	-0.370
SA	0.107	0.270	0.264	0.098
PTL	0.000	-0.212	0.059	-0.211

To further investigate the association between the subscales of the two instruments, a canonical correlation was performed using SAS version 6.12a (1996). The results suggested that the canonical correlation of 0.754 was significantly different from zero (Wilks' Lambda = 0.298, $p = 0.056$). The canonical correlation is the correlation computed from two new composite variables, or canonical variates, formed from the subscales of each of the instruments; the canonical correlation is the maximum correlation obtainable from the subscales of each of the instruments.

It is of interest to interpret the canonical variates for each instrument. To do this, the correlation between each subscale and the new composite variable is examined. The stronger the correlation, the more the subscale is contributing to the new composite variable. The canonical coefficients (or composite weights) and the correlation between each subscale and the new canonical variate are reported in Table 14.

The correlations between the individual subscales of the TPPI and the TPPI composite scores were examined to interpret the composite score. Only correlations greater than 0.25 were interpreted. These correlations suggested that the Teacher Actions subscale was the most potent indicator the total composite score of the TPPI. Further, the Philosophy of Teaching and Learning subscale contributed to the composite.

For the ESTEEM instrument, the canoncial coefficients and the correlations between the individual subscales and the ESTEEM composite are presented in Table 15. The correlations between the ESTEEM subscales and the ESTEEM composite score were examined to interpret the canonical variate. These correlations suggested that the EST 3 subscale, Context Specific Pedagogy is the most potent variable in determining classroom practice. The second most potent variable was EST 4, Content Knowledge. Note that the Context Specific Pedagogy subscale is

positively associated with the composite score and Content Knowledge is negatively associated with the composite score.

Table 14

Canonical Correlation Results of the TPPI

Subscale	Raw Canonical Coefficient	Correlation with Canonical Variate	Correlation with ESTEEM Composite
TC	-0.515	0.144	0.108
TA	1.015	0.912	0.688
SA	0.427	0.249	0.188
PTL	0.126	0.334	0.252

Further insight can be gained by examining the correlations between the subscales from one instrument and the canonical variate formed from the subscales in the other instrument. In the last column of Table 14, these correlations suggest that Teacher Actions is highly associated with the classroom practice composite. Philosophy of Teaching and Learning also appears to be associated with classroom practice. Both of these correlations between beliefs and the practice composite are positive.

Table 15

Canonical Correlation Results of the ESTEEM

Subscale	Raw Canonical Coefficient	Correlation with Canonical Variate	Correlation with TPPI Composite
EST 1	-0.580	-0.274	-0.206
EST 2	0.045	-0.297	-0.224
EST 3	1.234	0.427	0.322
EST 4	-0.894	0.366	-0.276

Correlations between the ESTEEM subscales and the composite score of the TPPI are presented in Table 15. Context Specific Pedagogy appears to be positively associated with the teacher beliefs composite, while Content Knowledge is negatively associated with the TPPI canonical variate. These results suggested that how the teacher views his or role in the classroom, and the teachers philosophy about teaching and learning, will define his/her constructivist beliefs. When the correlations between each subscale of the TPPI and the composite ESTEEM score were interpreted, the results also indicated that the Teacher Actions subscale may be the best indicator in describing classroom practice.

Interpretation of the canonical correlation results regarding the ESTEEM subscales indicated that Context Specific Pedagogy was the most potent variable in describing classroom practice and beliefs (Table 15). This result is not terribly surprising. This scale was designed to measure how a teacher modifies instruction based on what the students are doing and saying. A student-centered teacher will judge what actions are best based on the students' actions in the classroom. This ability to modify instruction according to student behaviors and explanations is considered to be a behavior that separates an "expert" teacher from one who merely follows a predetermined lesson, unable to diagnose the best course of action (Burry-Stock, 1993).

An unexpected result is the negative association between the EST 4 subscale and the composite variable of the TPPI. This result suggests that a teacher with student-centered beliefs will exhibit a lesser degree of content knowledge in the classroom. While this is contrary to previously reported literature (Gess-Newsome, 1999), the result did indicate an important aspect of student-centered instruction; that is, constructivist teachers do not tell students the answers, they invent ways in which students are able to explain scientific concepts for themselves. It is important to emphasize that scores on Content Knowledge on the ESTEEM instrument did not reflect ability or aptitude regarding scientific content. The scale was designed to measure how a

teacher exhibits content knowledge in the classroom. Therefore, a low score on the Content Knowledge subscale on the ESTEEM does not indicate a lack of ability.

Triangulation of the Data

Although the results indicate the difficulty in determining the relationship between and practice, a non-statistical interpretation of the data is provided. A comparison of the data sources was vital for the understanding of the relationship between beliefs and practices. Therefore, this non-statistical interpretation is presented to facilitate a global understanding of how the students in each Methods course compare across the instruments. The purpose of this interpretation was to provide a global representation of what students say compared to what they do. This interpretation was conducted based on the cluster analysis results.

The design of the study included three data sources for the purpose of triangulating the data to provide a more potent description of the relationship between beliefs and practices. Through statistical analysis, complicated patterns emerged, and clear interpretation became difficult. Indeed, as Isaac and Michael (1997) warned:

> Multiple measures of a given concept are often disappointing and inconsistent, pointing to the gravity of the measurement problem in the social sciences and the risks of false confidence where single criterion methods are employed. Such results are also awkward to report coherently (p. 97).

The following section is presented as a way to provide a visual representation of the relationships between secondary science preservice teachers beliefs and practices.

Three data sources were used in the study for the purpose of strengthening the interpretation of the relationships between stated beliefs and classroom practice. The relationships became complex, even unwieldy across the several subscales of the three instruments. In order to provide a global view of how each participant appeared across the instruments, the cluster analysis results from each of the three instruments were used. The

clusters showed mainly a group that was consistently above the mean on each subscale, a group that was below the mean for each subscale, and a group that was at or close to the mean for each subscale.

In Tables 16 through 18, each student is listed by their assigned case number. If the student appeared in the cluster above the mean, it is designated with a positive sign. If the student was in the cluster below the mean a negative sign is used, and if the student was in the cluster that represented the mean, a 0 was entered on the chart. These symbols were chosen because they provide a brief picture of overall patterns exhibited by individuals in the study. Clusters that consist of a pattern that falls above the mean for two subscales and below the mean for two subscales on the TPPI or ESTEEM are marked with a 0. Clusters with three subscales above the mean and one subscale below the mean on the TPPI or ESTEEM are marked with a positive sign, since these students were mostly above the mean. Clusters with three subscales above the mean and one subscale below the mean on TPPI or ESTEEM are marked with a negative sign. Since the CLES has six subscales, if the cluster consisted of four or more subscales above the mean, it was coded with a positive sign; and if 4 or more subscales were below the mean, it was coded with a negative sign. Only students who completed the three instruments were included.

Figures provided with each of the tables demonstrate the relationship between cluster membership across the three instruments. The relationships between the instruments were indicated by drawing a line between each instrument depending on which cluster a student belonged. The lines start from the CLES cluster, proceed through the TPPI cluster and end with the ESTEEM cluster. For example, in the Methods 1 cohort, the first student on the table, case number 0101 was in the high (above the mean) cluster for the CLES and TPPI, as indicated by the line drawn between the two instruments along the high cluster. For the ESTEEM, this

student was in the low (below the mean) cluster, and the line continues to the low ESTEEM cluster. The lines for the other cases were drawn in the similar manner. The numbers by each circle indicate the grand mean of each of the clusters for the instrument. These numbers are provided to compare the grand means of each cluster with each of the cohorts. Methods 2 did not have a mean cluster for the CLES.

Table 16

Comparison of Cluster Analysis Results for Methods 1 Cohort

Case Number	CLES	TPPI	ESTEEM
0101	+	+	--
0102	+	--	--
0104	--	0	+
0105	--	0	+
0106	+	--	+
0107	--	+	+
0108	+	0	+
0109	+	--	+
0110	+	--	0

Figure 1.

Cluster Comparisons for Methods 1 Cohort

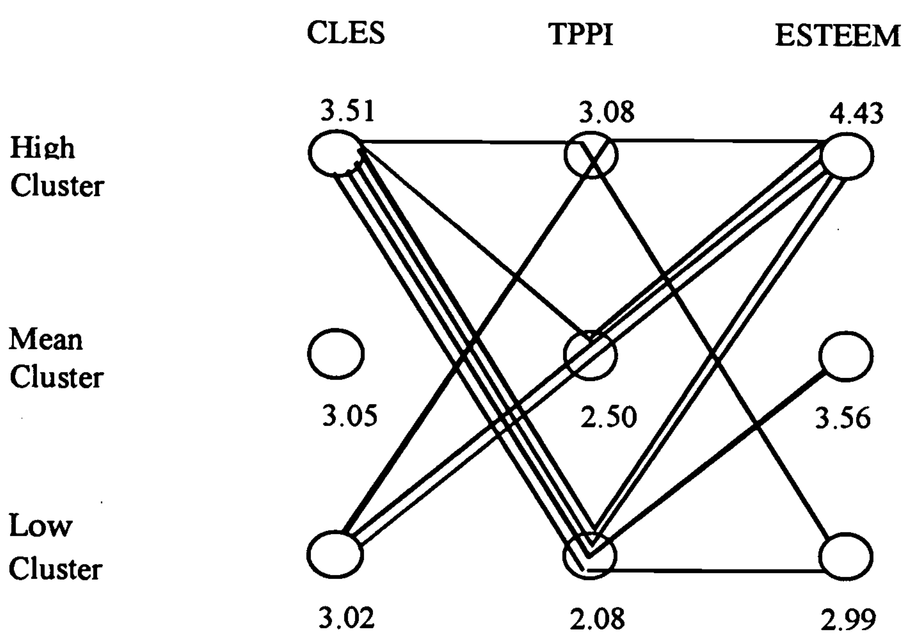


Table 17

Comparison of Cluster Analysis Results for Methods 2 Cohort

Case Number	CLES	TPPI	ESTEEM
0214	+	--	--
0215	+	+	+
0216	+	0	+
0217	+	0	+
0219	--	--	+
0221	+	0	0
0223	+	0	+
0226	--	0	+

Figure 2.

Cluster Comparisons for Methods 2 Cohort

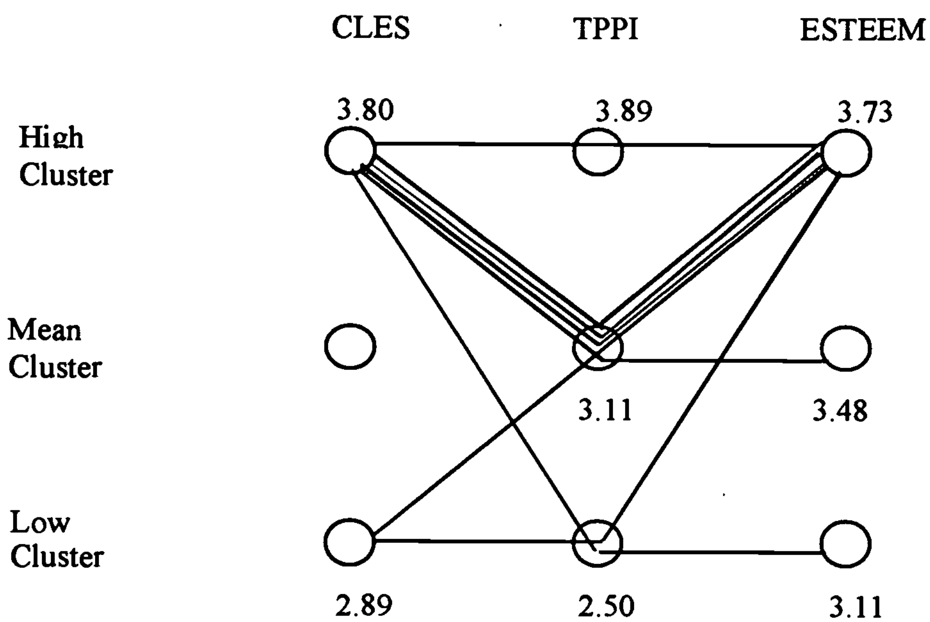


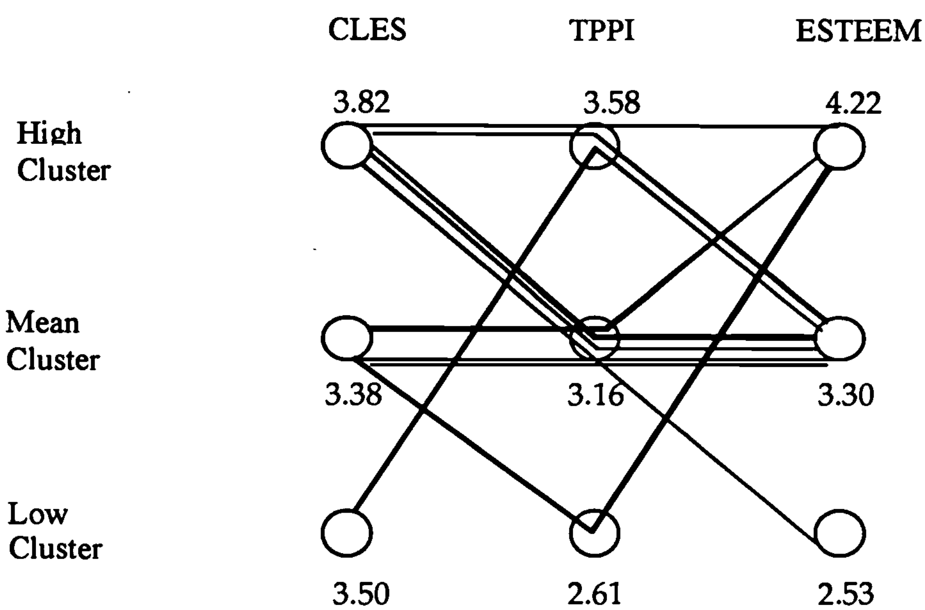
Table 18

Comparison of Cluster Analysis Results for Methods 3 Cohort

Case Number	CLES	TPPI	ESTEEM
0327	0	--	+
0328	--	+	0
0329	+	0	0
0330	+	+	0
0331	+	+	+
0333	0	0	+
0334	0	0	0
0335	0	0	0
0339	+	0	--
0340	+	0	0

Figure 3.

Cluster Comparisons for Methods 3 Cohort



Discussion of the Cluster Comparison Results

Inspection of the above tables and figures indicated there was no single pattern between self-reported beliefs and classroom practice (Shaw & Cronin-Jones, 1989). Past research indicated that beliefs are the best predictors of classroom practice (Pajares, 1992; Gess-Newsome, 1999; Czerniak, 1994). However, a key finding of the Salish I Research Project (1997a) was the opposite: new teachers expressed student-centered beliefs but exhibited teacher-centered actions in the classroom. The above results indicate that both avenues are possible, with an additional pattern: students reported teacher-centered beliefs (as evidenced by a negative sign on the TPPI cluster) and exhibited student-centered classroom practice (as indicated by the positive sign on the ESTEEM cluster).

The patterns across the instruments for the Methods 1 cohort display this pattern not previously reported in the literature: students who reported teacher-centered beliefs were observed teaching in student-centered ways. Two possible explanations for this pattern were uncovered by speaking with the students about the requirements for the practicum. First, students were explicitly required by the course instructor to teach an inquiry-based lesson while in the elementary schools. The lesson was sometimes the choice of the student, other times the choice of the cooperating teacher.

Secondly, students completed the CLES in regards to the classroom environment established by the cooperating teacher. Of the four students with teacher-centered beliefs who perceived the cooperating teachers' classroom to be student-centered, two exhibited student-centered teaching (0106 and 0109), one was a mixture of student and teacher centered (0110), and one taught in a teacher-centered way (0102). This demonstrated the impact of modeling of constructivist practices as a special importance in early preservice field experiences (Nespor, 1987).

Three students taught in a class they perceived to be teacher-centered. Of these three, one held student-centered beliefs and demonstrated student-centered teaching (0109). Two students reported a blend of teacher and student centered beliefs and taught in student-centered ways (0104 and 0105).

One student (0101) demonstrated the results of the Salish study: student centered beliefs with teacher-centered practice.

Although many combinations of beliefs and practice were revealed in Methods 1, the goal of the practicum experience was to do an inquiry, student-centered lesson. Most students taught in student-centered ways regardless of beliefs held.

Within Methods 2 cohort, students planned and taught lessons as a team of 3 or 4 students. Most students within this cohort reported a mixture of teacher and student-centered beliefs. Of these five students (0216, 0217, 0221, 0223 and 0226), four demonstrated student-centered practices, while the fifth (0221) showed a combination of teacher and student-centered practice. Of the two students with teacher-centered beliefs (0214 and 0219), one was teacher-centered in practice and the other was student-centered (0219). It was possible that student 0219 was in a group who planned a student-centered lesson and was following the lead of his teammates.

One student (0115) was consistently in the high cluster for each of the three instruments, which supports the research that concluded that beliefs and practice are congruent (Hollon, 1991; Janesik, 1982; Morine-Dershimer, 1983; Smith, 1989; Stein, 1988).

The students in the Methods 2 cohort completed the CLES based on observations of the cooperating teachers' classroom. The majority of students in this cohort held a combination of student-centered and teacher-centered beliefs and demonstrated student-centered practices. The

importance of the modeling of constructivist practices by the cooperating teacher was a factor contributing to student-centered practices by the practicum students (Nespor, 1987).

For students in the Methods 3 cohort, many of the tapes viewed included the practicum students teaching a lesson from a unit that was previously decided by the cooperating teachers within the school. While the lesson was predetermined by the cooperating teacher, the practicum students were free to decide how to instruct the class. The lesson provided for student autonomy and decision-making. The built in student-centered features of the lesson helped the student with teacher-centered beliefs (0327) show student-centered practice.

To determine the relationships between beliefs and practices for Methods 3 students, the CLES results need to be disregarded momentarily. The predominant pattern with Methods 3 students was conceptual (teacher and student centered) beliefs with conceptual practice, as evidenced by four of the ten total students (0329, 0334, 0335, 0340). Two students held student-centered beliefs and taught in conceptual ways (0328 and 0330). The one student with teacher-centered practice held conceptual beliefs (0339). One student (0331) held student-centered beliefs and demonstrated student-centered practice. The general trend validated previous research: beliefs guide practice (Pajares, 1992; Gess-Newsome, 1999; Czerniak, 1994).

With the inclusion of the CLES results, the trend becomes closer to the results of the Salish study, that beliefs about teaching were more student-centered than practice. Methods 3 students completed the survey regarding how they perceived their own classrooms, not that of the cooperating teacher. Half of the students perceived their classrooms had features reflecting constructivist strategies. This perception was different from classroom practice, which was a mixture of teacher-centered and student-centered practices.

General Results

The following general conclusions were based on the interpretation of the evidence presented previously and the results of the triangulation of the cluster analysis presented at the beginning of this chapter.

1. Patterns of preservice science teachers beliefs were complex. The relationship between beliefs and practice was inconsistent. For Methods 1 and Methods 2 students classroom practice and beliefs rarely coincided. The relationship between beliefs and practice were more consistent with Methods 3 students.

2. When secondary preservice science teachers reflected on aspects of a constructivist classroom, relevance and cooperative learning were identified as the most important features. However, noticeably lacking was the shared decision making process concerning the management of the classroom. While participants reported that students are able to question the activities and pedagogical decisions of the teacher, students are not necessarily perceived to have autonomy in designing activities or assessments.

3. Themes of relevancy, cooperative learning, and the establishment of an intellectually risk-taking environment were rarely reported by Method 1 students in open-ended questions, but were an emerging theme in responses of Methods 3 students.

4. The classroom environment of the cooperating teacher was important to demonstrate constructivist strategies. When students received support in developing constructivist lessons, they tended to teach in student-centered ways regardless of their beliefs. As students gained more experience in making pedagogical decisions, and less support from the cooperating teachers, practice more closely resembled beliefs.

5. Most students without prior coursework in the philosophy and history of science did not respond to questions regarding the nature of science. The majority of students who did complete this coursework defined science as a process that attempts to understand the natural world.

6. Descriptions regarding the role of the teacher were multi-faceted. The role of the teacher was most frequently described as: providing activities, making connections, using students areas of interest to select topics, and using *National Science Education Standards* to guide instruction.

7. Descriptions reflecting the nature of learning were usually one dimensional. Teacher candidates most frequently described evidence of learning as the ability to explain concepts to others. Methods 2 and 3 students included a second description as the applying information to a new situation or as a way to expand previous knowledge.

8. Descriptions of preservice science teachers regarding how they view their role in the classroom may be an important indicator in determining their constructivist beliefs and classroom practice.

The relationship of how preservice science teachers view teaching and learning and their decisions on how to teach in the classroom are complex. Conclusions of previous studies report that it is possible to predict behavior from what people say they will do (Czerniak, 1994; Gess-Newsome, 1999; Pajares, 1992). However, a conclusion of this study is that it is difficult to predict if a preservice teacher will exhibit teacher-centered or student-centered actions in the classroom based on self-report instruments designed to extricate beliefs about effective teaching and learning.

This one conclusion is important for instructors of science methods courses to consider. Stated beliefs do not necessarily manifest into desired practice. The field of education is replete

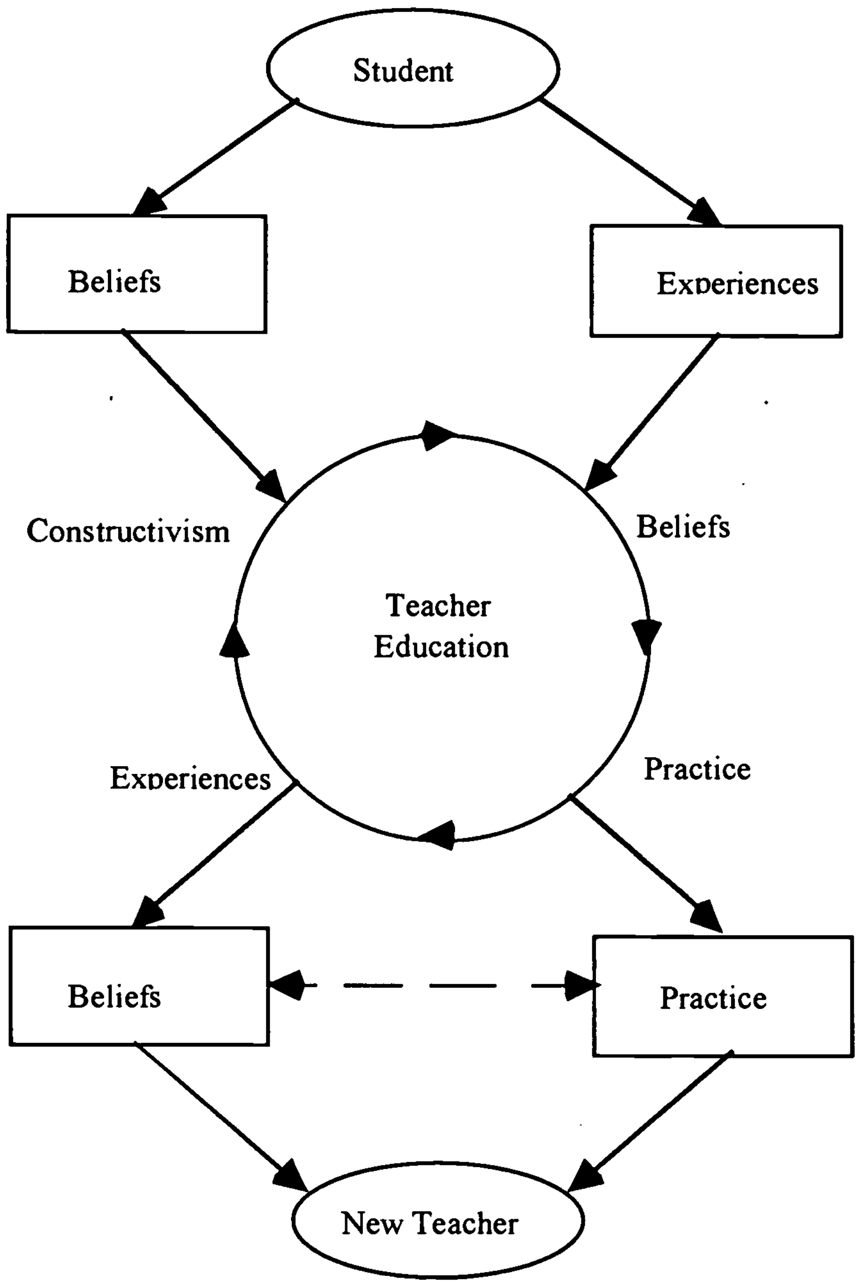
with jargon which is not difficult for students to parrot to professors (Brockmeyer, 1998). Instructors responsible for the education of future teachers must not assume that if students are able to use words such as "inquiry" and "constructivism", that students fully understand how these translate into effective science instruction.

The interesting pattern of student-centered practice with teacher-centered beliefs indicates a need for reflection by preservice teachers to understand why constructivist strategies are important. Preservice teachers were able to demonstrate student-centered teaching practices, but they do not hold beliefs congruent with constructivist practices. Unless the beliefs of the preservice teachers with this pattern understand the relationship between what they believe affects what they do, they may revert to more traditional ways of teaching when the support of the cooperating teacher is no longer available.

Figure 4 provides a representation of the role of reflection in teacher education. When students enter a teacher education program they bring with them experiences which have shaped their beliefs regarding teaching and learning. The role of the teacher educator is to find out what these beliefs and experiences of the students are. It is also the responsibility of the teacher educator to provide an opportunity for the beliefs to be examined periodically throughout the program. The circle of teacher education represents the constant cycle of reflection. Preservice teachers need to reflect on their beliefs, the experiences that shaped their beliefs, pedagogical decisions made while teaching students, experiences with children, observations of inservice teachers, educational research regarding best practices, science education reforms, the nature of science, the role of the teacher, and the nature of learning.

Figure 4.

The Role of Reflection in Teacher Education



The program needs to provide experiences that will challenge beliefs, opportunities to observe constructivist strategies, and provide time for reflection on all aspects of the process of

becoming a teacher. Teacher educators need to be especially cognizant of students with traditional beliefs and provide discrepant events that cause a disequilbrium regarding the traditional beliefs held and student-centered practices.

The student and the teacher educator should not be the only members of the team creating a new teacher. Cooperating teachers can provide the vital link between research and practice. When students see how reform literature and relevant educational research translate into effective teaching practices, this would help dispell the "ivory tower" perception of research.

The dashed line between beliefs and practice indicates the crucial link in the preparation of new teachers. Beliefs guide practice, and it is not enough that the beliefs held and classroom practice be congruent. They must also be congruent with constructivist strategies described by science education reforms. When this occurs, new teachers will be better prepared to face the daily challenges of teaching.

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AWAKENING THE SCIENTIST INSIDE: GLOBAL CLIMATE CHANGE AND THE NATURE OF SCIENCE IN AN ELEMENTARY SCIENCE METHODS COURSE

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Developing accurate understandings of the nature of science has long been a goal of science education (Lederman, 1992) and is currently emphasized in science education reform documents as a principal component of scientific literacy (American Association for the Advancement of Science [AAAS], 1990; 1993; National Research Council [NRC], 1996). Despite the longevity of the nature of this instructional goal and the many efforts undertaken to achieve it, research has consistently shown that K-12 students do not attain desired understandings of the nature of science (Duschl, 1990; Lederman, 1992; among others). A primary factor related to this lack of achievement is the fact that the vast majority of elementary and secondary teachers rarely address the nature of science explicitly in their science instruction. Certainly, much of this failure is due to the lack of emphasis on the nature of science in the science content and science methods courses of many teacher preparation programs.

Many have argued that science and technology based issues provide an ideal context for enhancing students' and teachers' understandings of the nature of science (Bentley & Fleury, 1998; Collins & Pinch 1998; Spector, Strong, & La Porta,1998). Such issues present the "messiness" of science-in-the-making and bring students into direct contact with the values and assumptions comprising the nature of science. Furthermore, science and technology based issues situate lessons about science in the context of learning relevant science content. Finally, science and technology based issues, such as global climate change, have the potential to connect

abstract scientific concepts to students' lives. The fact that they are often featured in popular media reports only increases the chance that students will find them relevant and interesting.

In this paper, one instructor's use of the issue of global climate change to integrate nature of science instruction into her elementary science methods course is described. Students' responses to the course are also reported, including changes in their views of the nature of science, global climate change, and teaching science at the elementary level.

The Nature of Science

Philosophers of science continue to adopt divergent positions on the major epistemological issues of science and scientific knowledge (Driver, Leach, Millar, & Scott, 1996), which suggests that the nature of science is in itself tentative (Lederman, 1992). Clearly, the nature of science is a multifaceted concept, apparently as difficult for experts to define as it is for students to learn. Presently, no consensus exists among philosophers of science, scientists, or science educators as to a precise definition or characterization of the nature of science. However, Lederman and his colleagues have recently argued that the majority of the disagreements about what constitutes the nature of science are irrelevant to K-12 instruction (Smith, Lederman, Bell, McComas, & Clough, 1997). Additionally, Lederman and his colleagues have suggested that consensus does exist on many aspects of the nature of science that are accessible and relevant to K-12 students (Bell, Lederman, & Abd-El-Khalick, 2000; Lederman, 1999; Lederman & Abd-El-Khalick, 1998; Smith et al., 1997). Included among these are the concepts that scientific knowledge

- Is tentative (subject to change).
- Is empirically based (based on observations of the natural world).
- Is subjective (theory-laden).

- Is partly the product of human inference, imagination, and creativity (involves the invention of explanation).
- Is socially and culturally embedded.
- Necessarily involves a combination of observation and inferences.

One additional aspect not currently addressed by reform documents but closely related to an understanding of the role of observation and inference is the function of and relationship between scientific theories and laws. While these aspects of the nature of science are listed separately here, they are actually closely interrelated. It would be incorrect to view any of them as standing alone. This characterization of the nature of science was used in the present investigation and is consistent with the vision supported by recent science education reform documents (AAAS, 1993; NRC, 1996).

Global Climate Change

The topic of global climate change/global warming (GCC/GW) illustrates many aspects of the nature of science as expressed by science education researchers (Bell et al., 2000; Lederman, 1999; Lederman & Abd-El-Khalick, 1998; Smith et al., 1997). Though global warming is treated as empirically proven by many members of the popular and scientific press, an examination of the literature on global warming illustrates the tentativeness of this concusion (see, for example, Easterbrook, 1992).

Study of the topic of GCC/GW is empirically based, and theories about future global climate are empirically driven. The computer-generated global circulation models from various agencies that produce differing forecasts of temperature change and sea level rise are subjective, based upon the algorithmic approximations of climate developed by different climatologists. These models and other research focused upon GCC/GW are based upon human inference,

imagination, and creativity (see, for example, Baskin, 1995; National Aeronautics and Space Administration, 1994).

The topic of GCC/GW is a common theme in newspaper stories and is discussed regularly by international agencies such as the United Nations. Politicians hotly debate legislation to regulate greenhouse gas emissions to mitigate climate change. GCC/GW is culturally and socially embedded, and common misconceptions about GCC/GW are based upon portrayals in the culture. This presents a special opportunity for instructors to use GCC/GW as an example of why citizens must be responsible for developing their own conclusions about issues, and not be led by the press and persons with particular agendas.

Clear definitions of three science concepts are essential to understanding the content used in this study: the greenhouse effect, global climate change, and global warming. The *greenhouse effect* refers to the cumulative impact of various atmospheric gases on the temperature of the Earth. There is great confidence among scientists that the greenhouse effect has been heating the Earth for at least three billion years, enabling the existence and evolution of living organisms (Moran & Morgan, 1994). *Global climate change* refers to the cycle of temperature shifts and the accompanying changes in other aspects of the Earth system over the long term. Climatologists have generated a vast body of evidence to support their idea that long-term average global temperatures have both increased and decreased at various times in the past. *Global warming* refers to the heating phases in the cycles of global change. Global warming is, at present, a controversial theory receiving a great deal of attention, because recent evidence of human-induced global warming points to potentially disastrous outcomes (Vogel, 1995).

Method

The purpose of this study was to assess the influence of nature of science instruction embedded in the context of a familiar controversial science and technology based issue on elementary preservice teachers' understandings of nature of science. The issues selected for this study were global climate change and the more controversial issue of global warming.

The Setting

The participants were 15 students (all female) in the semester-long elementary science methods course at a mid-sized university in the eastern United States. Ages ranged from 20 to 28 years old. Most were fourth-year students enrolled in a 5-year BA/MT program, but three were enrolled as postgraduates, working toward the MT degree.

The science preparation of the students varied greatly. Two of the three postgraduates had degrees in environmental science, and the other majored in psychology. Of the fourth-year students, four were majoring in English, four in psychology, two in history, one in anthropology, one in cognitive science, and one in mathematics. The general college requirements in science for admission to the elementary education program at this university stipulated students must have a total of 6 credit hours in science. There was no laboratory course requirement. The actual number of college science courses completed ranged from two to eight, with an average of three courses. Although the College of Arts and Sciences had recently developed a set of three science courses specifically designed for nonmajors and elementary education students, only two of the 15 students indicated they had taken such a course.

The instructor was a former elementary teacher with almost 20 years of K-12 teaching experience, much of that in teaching primary grades. She held an Ed.D. in Science Education and an M.Ed. in Early Childhood Education. In addition to the instruction received in her degree

programs, the instructor had participated in a variety of meteorological-based in-service programs. For example, she was trained by the American Meteorological Society (AMS) as a member of the cadre of teachers in the Project Atmosphere project, and she had been exposed to research on global climate change presented by the leaders in the field (Smith, 1994). She had attended sessions on global climate change and presented papers on teaching global climate change at national AMS conferences and had interacted with many climatologists, both at her own institution and through the AMS (Matkins, 1997). She had presented AMS materials on the topic of global climate change several times at regional and national meetings and was fluent with the topic. As a result of these experiences, the instructor had incorporated the topic of GCC/GW into her elementary science methods course for a number of years. She did this because of an interest in meteorology and global climate change and a belief that understanding these topics would lead to better understanding of the scientific enterprise.

In the fall of 2000, this instructor teamed with another science educator (the second author of this paper) who had experience in teaching the nature of science to preservice teachers. Together they designed and implemented an elementary science methods curriculum that combined study of the GCC/GW issue with explicit examination of the nature of science and ways it may be revealed through the study of science and technology based issues.

The Course

EDIS 589, Teaching Elementary Science, is a required three-credit course for all fourth-year students and postgraduate MT students in the elementary education program at this university. The course emphasizes the development of the skills and strategies necessary to teach elementary students grade-appropriate science content and processes. In conjunction with the more typical topics in elementary methods, approximately 9 hours of class time were devoted to

specific instruction in global warming and nature of science. Another 9 hours were devoted to other activities in which explicit references were made to the nature of science. Assignments included readings from popular periodicals and climatology literature. The instructor led the students in several activities related to GCC/GW. Following is a brief description of how the nature of science was integrated into global climate change instruction and other topics in the course.

Eliciting prior knowledge. The first activity consisted of a session designed to elicit students' prior knowledge about GCC/GW without penalizing them for misconceptions. The instructor asked students to raise their hands if they thought the greenhouse effect was beneficial to the earth environment, and then asked students to raise their hands if they thought the greenhouse effect was harmful to the Earth environment. She recorded the number of hands raised each time and, without discussion, proceeded directly into the next phase of the lesson with the question, "What do you think you know about global climate change?" Student groups were given time to discuss and record their ideas. Group representatives then presented their ideas to the class. The instructor refrained from adding information or rating the answers in any observable way.

Introductory discussion. The next class period involved a PowerPoint presentation and discussion about global climate change and global warming. Distinctions were drawn between the greenhouse effect, global climate change, and global warming. The instructor referred to the ideas generated by the students in the first activity and invited class questions and discussion about these ideas. She placed emphasis upon describing the greenhouse effect as a natural process that actually enables life on Earth. Discussion of GCC/GW centered upon the proposed

relationship of temperature to carbon dioxide, with mention of other greenhouse gases and of complicating feedbacks, e.g., clouds, increasing plant growth, and melting ice caps and glaciers.

"Mystery Tube" activity . A few class sessions later, the second author joined the class as guest instructor and led the group in the "mystery tube" activity (Lederman & Abd-El Khalick, 1998). This activity emphasized the roles of human observation, inference, and imagination in the development of scientific knowledge and illustrated the tentative nature of scientific knowledge. The activity also showed that scientific models are not meant to be exact copies of reality. The guest instructor concluded by leading a discussion in which the preservice elementary teachers reflected on the activity and were encouraged to explicitly link the activity to key aspects of the nature of science.

Basic process skills activities. As the semester progressed, students participated in a sequence of investigations whose primary goal was the development of the ability to teach the basic and integrated process skills to elementary students. Prior to the "mystery tube" activity, the instructor had introduced activities during which the students practiced making observations and inferences. Over the next few weeks, other activities provided opportunities for connecting nature of science understandings to content. The instructor led the class in activities designed to learn how to observe and infer and to discriminate between the two processes. Two of these observation/inference activities were the Mystery Box (Slattery, 1997) activity and the Footprints activity (Earth Science Curriculum Project, 1973). These activities facilitated discussion about the tentativeness of conclusions and about the ability of the scientific body of knowledge to change as observational ability advances through technology.

Integrated process skills activities. The first structured investigation using the integrated process skills employed the paper helicopter (Cothron, Giese, & Rezba, 1993). After

manipulating the paper helicopters and determining some properties of the helicopters, the class established a question they wanted to investigate. The instructor led discussion to determine the procedure to be used and established protocols for data recording. Students performed the investigation, charted and graphed their data, and drew conclusions. The next investigation occurred a few weeks later, the Stopper/Popper (Karplus & Thier, 1967). The instructor introduced students to the Science Curriculum Improvement Study mechanisms called stopper poppers and gave student teams a general idea of the investigation they were to do. Teams were then directed to perform the investigation and record the results with all the components used in the paper helicopter activity. Those components were (a) experimental design diagram stipulating independent and dependent variables, hypothesis, levels of the independent variable, number of trials, constants, and control group, (b) procedure, (c) data chart, (d) line graph with best-fit line, and (e) analysis and conclusions. These investigations provided opportunities to discuss the variability of data and the impossibility of keeping every variable except the independent variable constant in an investigation.

Weather observations and measurements. During the period students were developing skills in designing and interpreting results of investigations, they were introduced to the online interactive Student Cloud Observations Online (S'COOL) project (http://asd-www.larc.nasa.gov/SCOOL/SCOOL.html). The instructor took the class outside for about 15 minutes of class for three successive class periods, and the class identified clouds and measured ambient temperature, atmospheric pressure, and relative humidity. As one of their assignments, students made observations during specific NASA satellite flyover times and reported their data to the NASA S'COOL Website. This activity also emphasized the importance of observation in science and the tentativeness of scientific conclusions. As will be seen with the final global

climate change activity discussed later, the S'COOL activity provided a concrete reference for students when specific cloud types and the various feedback mechanisms were discussed.

Readings and discussion. Various reading assignments throughout the semester supplemented student understandings about GCC/GW (see Appendix A). One set of student reading assignments dealt with opposing views about reducing carbon monoxide emissions. The class that day was titled, "Even Scientists Disagree." In an article in *Science*, Romm Levine, Brown, and Petersen (1998) stated that the United States should take measures to reduce carbon dioxide emissions. In contrast, Michaels, in the *World Climate Report* (1995), stated that reduction of carbon dioxide emissions would be economically catastrophic, and there was not enough evidence that warming was due to emissions. Discussion of these readings began with a review of the information and the perspectives presented and concluded with discussion about what these disagreements could reveal about science.

Meetings with scientists. Early in the semester, each student team was assigned a mentor on the faculty of the university's Department of Environmental Science. These mentors were all faculty members and researchers in the department. Faculty mentors were selected based upon recommendation and their willingness to participate. The teams were responsible for meeting twice with their mentors and for producing a written reflection on those meetings. The instructor directed the teams to use the first meeting to gain understanding of the current research on global climate change and global warming. The purpose of the second meeting was to discuss with their mentor ideas for translating this concept into lessons for elementary students. Student teams were given a 4-week range of time early in the semester in which to complete their first meetings and a similar range of time toward the end of the semester in which to complete their second meetings.

Modifying elementary science activities. As the students progressed through the semester, they became more fluent with finding and using elementary science activities from various sources, including tradebooks and the Internet. One problem with some activities is that they are incomplete or oversimplified or they teach misconceptions.

About midsemester, a lesson focused on one such activity that presented a model of the greenhouse effect. This activity used plastic bags, thermometers, and light sources to demonstrate the endpoint difference in temperature in open and enclosed (greenhouse) environments. Because it oversimplifies the interactions involved in the greenhouse effect, the activity was discussed at length in "Bad Science," a Website devoted to debunking science misconceptions common in popular literature (http://www.ems.psu.edu/~fraser/BadScience.html). During this class session, students discussed this activity and its problems and related it to the "mystery tube" activity earlier in the semester, where they had determined that scientific models are useful but not exact copies of reality. Following discussion of the greenhouse activity as written, students discussed ways the activity might be modified in order to produce a better model. In conclusion, students discussed whether they would ever be able to create the "perfect model."

Fossil activity. In a later lesson, the second author conducted a nature of science lesson using fossils (Lederman, Abd-El-Khalick, & Bell, 2000). First, he presented pairs of elementary preservice teachers with a fossil fragment and asked each to make a detailed drawing of the fossil. Next, students were directed to discuss within their teams what they thought the rest of organism would look like and complete their drawing of the fossil fragment by sketching in the rest of the organism. They were then asked to present their drawings to the class and to describe the habitat, food, and adaptations of the inferred organisms. A representative of each preservice

teacher-team was asked to describe the properties upon which they based their inferences. The second author led a discussion on the actual work of paleobiologists and how the class activity compared to paleobiology, the role student prior knowledge played in the extrapolation from the fossil fragment to the inferences about the organism it represented, and the creativity and imagination students and paleobiologists used to interpret incomplete evidence.

Reading and discussion: Theories and laws. One of the assigned readings during this time (see Appendix A) was a newspaper article discussing misconceptions about the definition of a scientific theory and a scientific law (Springston, 1997). Students discussed this reading, and the instructor emphasized the point made in the article that theories do not become laws and ideas do not become laws when they are "proven." The instructor also supplemented the information from the newspaper article with the point that the popular cultural definition of the words "theory" and "law" differ from definitions of those two words in the culture of science. As in many previous lessons, the instructor reviewed with students the difference between a scientific observation and a scientific inference, and the relation of observations to laws and inferences to theories.

Oobleck activity. As part of a set of lessons on commercial science curricula, the instructor led the students in a shortened version of the Greater Explorations in Mathematics and Science (GEMS) *Oobleck* activity (Sneider, 1985). Student teams were each given a sample of the green non-Newtonian fluid made of cornstarch, food coloring, and water and directed to determine the properties by making observations about the substance. After a brief period of exploration, student teams reported their discoveries to the class, and a set of descriptive properties were agreed upon. The instructor then led the class in determining what "Laws of Oobleck" they could agree upon. The "Laws of Oobleck" were displayed for students, and

students discussed how the process they used in the Oobleck activity was similar to the process scientists used to determine what is a law.

Culminating experience. During the last few classes of the semester, the instructor led the students in a discussion and set of activities connecting global climate change with the nature of science. During this time, observations made by the students in the S'COOL assignment were connected to the different feedbacks various cloud-types yielded in the Earth system and how those feedbacks could affect global temperature over time. The instructor led the students in a hands-on, cloud-making activity and discussion of how an increase or a decrease in clouds at various heights might impact climate. The students and instructor discussed the nature of climate observations and the tentativeness of climate change forecasts. Student groups discussed the outcomes of the two meetings with their mentors from the university's Department of Environmental Science. The instructor led the students in discussion of differences in the opinions of the various mentors about global warming and how that illustrated the role of human creativity and imagination in the development of scientific ideas. She also emphasized that these scientists' own ideas were culturally and socially embedded, just as were her own and the students' ideas.

Data Collection

A questionnaire (Appendix B) was administered to all students at the beginning and end of the course. The nine-item, open-ended questionnaire was used to assess participants' understandings of nature of science and GCC/GW. Five of the items focused on the previously mentioned aspects of nature of science, and four of the items related to GCC/GW. Two questions about the impact of the mentor meetings and instruction on global climate change were added to the end-of-course questionnaire. Following each administration of the questionnaire, six

participants were interviewed to help establish validity of the questionnaire responses. Students were purposefully selected for interviews to produce a stratified sample based on their science backgrounds. During the interviews, participants were provided with their responses to the questionnaires and asked to explain and elaborate on their responses. The interviews were audio-recorded and transcribed for analysis.

Data Analysis

Both authors analyzed the data. Interrater agreement was established through comparison of the analyses of three randomly selected questionnaires. Agreement was better than 90%. All questionnaires and the transcripts of the interviews were analyzed to generate pre- and post-instruction profiles of participants' nature of science and GCC/GW understandings. The generated profiles were searched for patterns, which were checked against the data and modified accordingly. Participants' pre- and post-instruction profiles were compared to assess changes in their nature of science and GCC/GW understandings.

Results

Results of the analyses of the preservice elementary teachers' responses to the questionnaire and follow-up interviews indicated significant pre- to posttest differences in their views of the nature of science and global climate change. Overall, the posttest responses reflected current understandings at a substantially higher rate than those of the pretest (Table 1 and Table 2). The sections following each table present a breakdown of the participants' pre- and posttest views through the use of summary statements and representative quotations. A coding system is used in the following sections to delineate whether specified data were collected prior to (Pre-) or after (Post-) nature of science/global climate change instruction and to identify individual participants (1 to 15).

Table 1

Percentage of Participants With Desired Views of Targeted Nature of Science Aspects

Nature of Science Aspect	Pre-Instruction	Post-Instruction
Empirical Nature of Scientific Knowledge	27	73
Tentative Nature of Scientific Knowledge	0	60
Role of Creativity in Scientific Knowledge	0	67
Subjective Nature of Scientific Knowledge	20	80
Cultural Influences on Scientific Knowledge	0	27

Pre-instruction views of the nature of science. Prior to instruction, participants' views of the nature of science were clearly inconsistent with the recommendations of current science education reforms. A large majority of participants expressed misconceptions about the empirical and subjective nature of scientific knowledge (73% and 80%, respectively). Furthermore, none of the participants' pre-instructional views were compatible with current understandings of the tentative nature of scientific knowledge, the role of creativity in constructing scientific knowledge, nor the influences of culture and society upon the construction of scientific knowledge.

The empirical nature of scientific knowledge. Only about 27% of the preservice teachers expressed current conceptions of the empirical nature of scientific knowledge in their pre-instructional responses to the questionnaire. The participants' familiarity with the use of evidence in science was reflected in the fact that all of them referred to the use of data and observations in the construction of scientific knowledge. However, most indicated that scientists rely *solely* on empirical evidence to *prove* their conjectures and theories. In general, these

participants did not appear to acknowledge the roles of inference and creative thought in the construction of scientific knowledge:

> A scientific theory is an idea that has been tested and scientists are still testing to prove the theory as true....A scientific law is a theory that has been tested and proven. (Pre-1)

> Art does differ from science because art doesn't set out to prove something and art can take on any shape and form and does not have to have proof or justification. (Pre-12)

The tentative nature of scientific knowledge. Tentativeness was another aspect of the scientific enterprise of which participants had some prior knowledge but, nonetheless, misunderstood to a large degree. For example, participants believed that different types of scientific knowledge is tentative to varying degrees, depending on the level of proof that can be ascribed to them. Theories, for example, were viewed in the vernacular sense as weakly supported ideas prone to revision.

> I believe that theories do in fact change—this is one of the main reasons they are just that: theories, and not facts. (Pre-6)

> A great example of [theory change] is the always-baffling unanswered question of how to lose weight. At least hundreds, if not thousands, of theories exist on this topic, many of which contradict one another and confuse the public. (Pre-2)

Participants' absolute views of scientific knowledge were also evident in their response to Item 2 concerning how scientists know about the structure of the atom. Consistent with their previously described views of the preeminence of empirical evidence, several respondents indicated that scientists view atomic structure directly.

> They can observe the insides of a very, very extremely magnified atom to determine what it looks like and what type of particles are found inside. (Pre-6)
> The majority saw scientific laws as proven beyond a shadow of doubt.

For these preservice teachers, scientific laws, along with facts and observations, constituted absolute knowledge that would never change. These participants also expressed the misconception of a hierarchical relationship between scientific theories and laws.

> It is important for a child to understand why scientific law holds authority, because it has undergone a tedious process of changing from a hypothesis to a theory and is accepted as a law because it has undisputable evidence to support it. (Pre-3)

> A scientific theory cannot necessarily be proven, whereas a law is believed to be a constant, accurate explanation of something in the science world that has been tested and re-tested. A theory is usually the first step in constructing, or formulating, a law. (Pre-9)

Most participants linked the tentativeness of scientific theories to the empirical nature of science. In fact, the collection of new data and the accumulation of counter evidence were typically cited as the sole source of change. The majority of participants (93%) made no mention of the possibility that scientific theories could change due to new insight or new ways of looking at existing data.

The role of creativity in constructing scientific knowledge. Participants' pretest responses to the fourth item generally depicted a seminal role for creativity in the processes of science. The majority of these preservice teachers came to the course with the picture of science as a creative and imaginative endeavor.

> Science and art are similar in that both rely on allowing the mind to run freely in order to acquire new knowledge of the respective disciplines. Without creativity, both fields would have died long ago. Both, however, are still alive and thriving due to creativity of the human brain. (Pre-2)

> Science has a method, but it is the scientists who expand this method, who work outside of the box, that are considered brilliant and ingenious scientists. (Pre-14)

However, none of the participants were able to go beyond this level of generality. When asked to elaborate on these views, the participants typically responded that scientists use

creativity when "designing experiments" and "thinking up new ideas." The role of creativity in interpreting data was largely ignored. Furthermore, all participants expressed the conception that science progresses through application of the highly regimented "scientific method," a view that is at odds with science as a creative endeavor. At best, it appears that these preservice teachers viewed creativity as playing a role only before the real science (i.e., scientific method) is applied.

The subjective nature of scientific knowledge. Interestingly, there were few pre-instructional responses reflecting the common misconception that scientific knowledge and the processes used to develop it are totally objective. Rather, the preservice teachers described a degree of subjectivity as inherent to the construction of scientific knowledge. However, most participants could speak of subjectivity only in a general way, such as differences in "data interpretation." Furthermore, a few of the participants' pre-instructional responses described subjectivity in the negative sense that "...sometimes people 'see' simply what they want to believe" (Pre-6).

Cultural influences on scientific knowledge. None of the 15 participants made any reference to cultural influences on the scientific enterprise in their pre-instructional responses to the questionnaire and follow-up interviews.

Post-Instruction Views of the Nature of Science

Participants' post-instructional responses to the questionnaire and follow-up interviews reflected substantial movement toward current conceptions of the nature of scientific knowledge. While not every participant experienced gains in understanding of all five targeted aspects, the overall picture was very encouraging (Table 1). The following discussion highlights changes in participants' views of the nature of science following explicit instruction on the nature of science and the GCC/GW controversy.

The empirical nature of scientific knowledge. As in their pretest responses, all participants referred to the use of empirical evidence in their responses to the posttest. However, the participants' post-instructional views differed in that a high percentage (67%) realized that scientists often go beyond the observable when constructing scientific ideas and theories.

> We teach theories because not everything is explainable through observations...ideas we have about stellar evolution are inferences about things we know about the composition of stars. (Post-1)

> Different scientists look at the same topic in different lights drawing from their own theories, backgrounds, and research. While they have the same data, these factors lead them in different directions and approaches to the topic. (Post-12)

In contrast to participants' pre-instructional responses, references to "proving" scientific ideas as "true" were largely absent from the post-instructional responses. One participant did, however, define "inference" as "not proved by evidence" and described scientific laws as capable of being "proved by visible evidence" (Post-3).

The tentative nature of scientific knowledge. Post-instructional responses indicated important shifts in the participants' largely absolute views of scientific knowledge. While all participants continued to express the belief that theories change because of new evidence, a minority (33%) also described theory change as a result of new ways of looking at existing evidence.

> I think theories change...the theories about dinosaur extinction have changed because of new evidence and a new perspective on data. (Post-1)

> Since theories are founded on interpretations of observations, different scientists may propose different theories despite potential use of the same set of data. (Post-11)

All of the participants also spoke of the explanatory function of theories, something that was entirely lacking in their pre-instructional responses. In fact, in a majority of the post-

instructional (67%) responses, participants contrasted theories and laws by their function, rather than level of "proof."

> A theory is based on explanation/inferences that attempt to explain why phenomena happen in a certain way, while a law generalizes/summarizes how a phenomenon behaves/acts (based on observations). (Pre-3)

> Theories are based on inferences. The theory of evolution is composed from inferences about how the world has changed. Laws are based on observations. Newton's laws describe the way objects move. (Pre-5)

Post-instructional responses also tended to contrast theories and laws by the types of knowledge from which they are derived. The participants clearly saw theories as inferential in nature and scientific laws as generalizations. This contrasted markedly with their pre-instruction misconception that laws are of the same type of knowledge and are, in fact, derived from theories.

The role of creativity in constructing scientific knowledge. About 67% of the participants expressed adequate post-instructional views of the role of creativity and imagination in the generation of scientific knowledge. According to these participants, creativity permeates the scientific process, both in the design of experiments and in the interpretation of data. While the participants contrasted art and science in terms of the level of rigor and justification required, most agreed that "Creativity drives both scientists and artists" (Post-2). The change in participants' views was further emphasized by their rejection of the conception of a single scientific method. Contrary to their prior beliefs, 73% allowed for many methods and creative approaches to the process of generating scientific knowledge.

> Not everything can follow the scientific method—like, if you're trying to find out about dinosaurs....I don't think that every time someone is going to state a hypothesis before they discover something. (Post-1)

The subjective nature of scientific knowledge. About 80% of the participants rejected the view that science is completely objective and rational in their responses to Item 5 of the posttest. Rather, they described how scientists' backgrounds, personal views, and biases toward the data potentially played a role in their interpretation of the data. Contrary to their pre-instructional responses, none of the participants cast subjectivity in a totally negative light.

> Scientists' interpretations of experiments and data differ because of the varying perspectives due to the scientists' background. (Post-1)

> Different conclusions are the result of different interpretations of data. Scientists draw varying inferences based on unique personal experiences, backgrounds, and systems of thought and belief. Every individual is the product of a unique set of life experiences, program of study, and mindset. All of these factors affect how a researcher interprets a given set of data. (Post-11)

Cultural influences on scientific knowledge. In contrast to the pre-instructional responses, in which the participants made no reference to cultural influences, 4 of the 15 participants (27%) described how cultural influences could affect the scientific enterprise and the knowledge it constructs. Three of these references to cultural influences described how the culture at large could affect what science is done and how it is received.

> [Without teaching theories] we would not see, for example, that the Copernican model that the earth revolved around the sun was widely unaccepted during his time because it rejected the Christian idea that the Earth is at the center of the universe and everything revolved around it. (Post-12)

Pre-Instruction Views of Global Climate Change and the Nature of Science

Pre-instructional views of the controversial science topic, GCC/GW, and the nature of science included many misconceptions and inaccuracies about the factors focused upon in this study (Table 2). Few students held any correct understandings about the greenhouse effect, global warming, or global climate change; all responses on the survey revealed some GW/GCC misconceptions. No student expressed correct understandings about theories and laws as they

related to GCC/GW. Table 2 is a summary of students' responses to the questionnaire (pre- and post-instruction) regarding their understandings about GCC/GW and about the nature of science as it related to the controversial science topic.

Table 2

Participants' Understandings of Global Climate Change and the Nature of Science

Concepts of GCC/NOS	Pre-Instruction %	Post-Instruction %
Greenhouse effect is natural and beneficial	13	60
Scientists differ on whether global warming is happening.	53	80
Greenhouse effect is a theory because laws are proven.	67	0
I would support government action to develop alternative energy sources even if it costs me money.	53	93
I learned something about the nature of science from my environmental scientist mentor.	n/a	67
I learned something about the nature of science from studying global climate change.	n/a	93

The greenhouse effect is natural and beneficial. Prior to instruction, most students believed that the greenhouse effect was harmful to the Earth's environment and potentially dangerous to life on Earth. About 33% confused the greenhouse effect and ozone layer depletion. Student responses ranged from statements that revealed blatant misconceptions to responses that used some correct descriptions and terminology. About 27% of the responses were stated so generally that it was not possible to determine if the participant held any correct understandings of the greenhouse effect. At the beginning of the class, a high percentage (60%) of the students

believed the greenhouse effect was caused by some sort of human interaction. Several stated disastrous outcomes should the greenhouse effect go unchecked.

> It is caused by a hole in the ozone layer which allows stronger sun rays in. The heat of the sun is slowly heating the temperature of the earth causing the polar caps to begin melting. This increases the amount of water in the ocean and leads to erosion on the shores and loss of land. (Pre-2)

About 13% of the students began the semester with a somewhat correct understanding of the greenhouse effect. These understandings contained references to the greenhouse effect as a phenomenon that warmed the earth and had a beneficial impact and did not contain discussion of the greenhouse effect as a human-induced event. However, even these students expressed other misconceptions, such as listing isotopes as greenhouse gases (C_{14}), naming gases that did not occur naturally prior to the 20th century (CFC's, first synthesized in 1928), and failing to distinguish between particles and gases. Even the most correct descriptions were not correct enough that one could reasonably expect any of the respondents to accurately teach the concepts to children. The most correct response follows:

> Certain particles, CFCs, C_{14}, and others form a blanket in the stratosphere that "insulates" the earth—keeps the earth warm by keeping heat emitted from the sun around the earth. (Pre-1)

<u>Scientists differ on whether global warming is happening.</u> Although no one had complete understanding of the greenhouse effect and global climate change, about half (53%) of the respondents appeared to understand that scientists were not certain about whether global warming is happening. The reasons ranged from uncertainties shared by scientists about what the data meant to uncertainty between scientists about how to interpret the data.

> Some scientists think we're in danger; others think that the earth is just experiencing normal climate variations. (Pre-1)

About 47% believed that scientists were certain that global warming was happening, consistent with the absolutist views of the nature of science held by many of the participants. Even these students, however, expressed the belief that scientists are uncertain about the rate of warming.

> They are certain that it is warming but whether or not the rate is dangerous is questionable. Not only b/c of lack of confidence/accountability in methods used to determine temperature/make predictions, but also because there have been climatic fluctuations before. The cycle may not be significantly abnormal. (Pre-3)

Greenhouse effect is a theory because laws are proven. When asked "Is the greenhouse effect a theory or a law?" 67% of the participants responded with "theory." The explanations were consistently based upon their understandings of the tentativeness of observations about the greenhouse effect. Their own misconceptions about the greenhouse effect and about the nature of scientific theories and laws were reflected in their belief that lack of evidence about the greenhouse effect explained why it was not a law. Some of these respondents stated that once the greenhouse effect was proven, it would become a law. Of those who stated the greenhouse effect was a law (20%), the explanation given was that the greenhouse effect was proven. Only 13% of the respondents stated correct connections between the kind of information encompassed by the greenhouse phenomena and the scientific nomenclature of theory and law.

> I would say that it is a theory only because it is probably difficult to obtain enough evidence to make this explanation indisputable. (Pre-3)

> If it were a law, it is probable that results/consequences of the phenomena would have to have been observed and recorded a number of times (it would become provable and a fixed phenomena). (Pre-9)

Knowing that students confused greenhouse effect and global warming, the instructors were interested in their reasoning and what this reasoning would reveal about their knowledge of

the tentative nature of science. Participants' pre-instruction beliefs about the greenhouse effect reflected conventional understandings about theories as unproven conjecture and laws as proven.

Support of government action to develop alternative energy sources. Consistent with the responses of 53% of the participants that scientists were certain about global warming, 53% indicated willingness to support the development of alternative energy sources even if the actions taken raised their taxes or cost them in other ways. An additional 20% supported action but were not willing to support this if global warming were the reason given.

> Yes, if I knew for sure that the normal sources of energy were devastating the environment. If I felt sure that global warming was caused by humans – that we were altering things to make it more severe. (Pre-1)

> Depending upon arguments for & against, at this point, no, because I don't know enough about it. (Pre-8)

Post-Instruction Views of Global Climate Change and the Nature of Science

Post-instructional responses about GCC/GW and also about the nature of science showed that participants' ideas changed substantially. Though not every participant moved to correct and complete understandings, a large portion of the class did (Table 2). Also, most participants were willing to support government action to encourage the use of alternative energy sources. The following sections highlight the changes in participant understandings of global climate change and the nature of science as it intersected with the study of global climate change.

The greenhouse effect is natural and beneficial. At the end of the semester, 60% of the class held the correct understanding of the greenhouse effect, in contrast to 13% at the beginning of the semester. The understandings expressed in the posttest questionnaire were generally more thorough and showed a deeper understanding of the processes involved in the greenhouse effect. Some respondents made a direct connection between the nature of models and the greenhouse

effect as a model. Given that many participants were confused about the greenhouse effect at the beginning of the study, the thoroughness and clarity of posttest responses is especially notable.

> To preface, the greenhouse effect is a bit of a misnomer. It does not operate in exactly the same way that an actual greenhouse does. While the walls and ceiling of an actual greenhouse contain heat pretty conservatively, the earth's atmosphere reflects quite a bit of radiation back into space, absorbs a bit of radiation, and transmits some of the heat emitted by the earth. Furthermore, the atmosphere is a dynamic system unlike the walls and ceiling of a greenhouse. Air circulates within the atmosphere, and the composition of gases is constantly changing. What is meant by the greenhouse effect is the effect of gases in the atmosphere on radiant energy flux and thereby on global climate. Some believe that increased CO_2 concentrations in the atmosphere are causing rises in global temperature. (Post-11)

> The greenhouse effect is a proposed explanation for increased Earth temperatures. It is not the same as "global warming," and often receives a negative connotation. The greenhouse effect is a model, much like a real greenhouse, that reflects gases held to the Earth by gravity that in turn insulates the earth's surface bacause of a loss of energy – we probably couldn't live on earth without some degree of greenhouse effect. (Post-9)

Scientists differ on whether global warming is happening. By the end of the semester, 80% of the students in the class had learned that scientists differ in their ideas about whether or not global warming is happening at a dangerous rate, as compared to 53% on the pretest. In the posttest responses, participants expressed an understanding of the function of inference in the development of scientists' ideas about global warming.

> Some scientists are certain that the Earth is warming at a dangerous rate. Some scientists are certain that the Earth is cooling, while others are certain it is all part of a cycle. They are all inferring different things based on the same data. (Post-4)

> Many are certain (and some are not) that the Earth is warming, although it's still very debatable if it's warming at a "dangerous" rate – that is a very bold inference/judgment to make based on the un-alarming data. Few scientists would likely say the warming rate is "dangerous." (Post-9)

Greenhouse effect is a theory because laws are proven. Prior to instruction, participants based their choice of "theory" or "law" upon whether or not they believed the greenhouse effect

was proven or not. After instruction, about 60% of the participants responded to the question with correct explanations about theories and laws, and all 60% referred to the nature of the reasoning as the justification for their answer. Furthermore, they used the science process nomenclature of observation and inference, as they had been taught in the course, to clarify their reasoning.

> The greenhouse effect is a law-if it is described as the reflective effect of the atmospheric gases on radiant energy. If, however, it is described as being the effect of changes in atmospheric composition on global climate change, it is a theory. Laws are based on strict observations while theories are founded on inferences, which involve the interpretation of observations. (Post-11)

Support of government action to develop alternative energy sources. Consistent with the change in beliefs about the tentative nature of science, about 93% of the participants said they would support efforts to develop alternative energy sources. Before, participants needed absolute proof to commit to supporting government actions. Many described non-nature of science issues as influencing their decisions but were, nonetheless, supportive.

> I think I would support such a program since alternative energy sources would reduce pollution – if nothing else. Moreover, since we are not sure that global warming is not occurring, it might be wise to take possible precautions in the event that it is happening. (Post-11)

Did meeting with your mentor change your views of the nature of science? During the post-interviews, 67% of the participants said they learned something about the nature of science from the two meetings held with their mentors in the Department of Environmental Science. Typically, these responses reflected discussions in the mentor meetings about the differences in opinions among scientists about global warming, and the tentative nature of scientific research.

> Meeting with our science mentor reminded me of the complexities of scientific research and the degree of interpretation involved. It is easy to forget that science is neither fully straightforward nor perfectly objective. (Post-11)

I realized that some topics in science are subjective, like the issue of whether or not global warming is occurring at a harmful rate and to what extent it's due to man's interaction with the environment or it's just a fluctuation in a climate cycle. (Post-1)

Did studying GCC change your ideas about the nature of science?

The topic of GCC/GW was chosen because it has been a consistent theme in the popular culture during the lives of these participants and because there was consistent and sometimes heated controversy over the predictions that various organizations made about the contribution of humans to perceived change. Nearly all (93%) of the respondents wrote that studying this topic altered their views of science. Explanations included references to the subjectivity of scientists, the tentativeness of science, the influence of the media on the culture, the influence of the culture on science, and discussion of changes in understanding of the content of global climate change.

It changed my views of science – studying global climate change made me realize that science is not always exact and conclusive. Opinions about global climate change vary within the community, which leads me to believe that often scientists' views about different scientific topics differ as a result of their perspective/background. (Post-1)

Studying global climate change likewise reminded me that it is often difficult to isolate and control the numerous factors at play in a given situation, as a result, it becomes a challenge to determine causal relationships. In addition disagreements occur within the scientific community. (Post-11)

Our studies enlightened me to the changing nature of science and also to the need to view science, its experiments and data over a vast period of time to get a more complete but still not totally complete picture of science. (Post-14)

Discussion

The use of the controversial science and technology issue of GCC/GW had a positive effect on participants' understandings of the nature of science. The topic dealt with scientific content of a complex nature and with theories and laws. It showed disagreement among scientists

in terms of data collection and interpretation and explored the impact of politics on the pursuit of science. Participants were also able to generalize these aspects to the scientific endeavor.

Though the participants recognized the subjective and tentative nature of knowledge about this controversial topic, they expressed a willingness to commit financial resources to governmental measures to counteract negative effects. This indicates a comfort level with understanding of the human perspective on science and an acceptance of the tentative nature of science without rejecting scientific conclusions. Respondents seemed to draw confidence from their understanding of the processes of observation and inference and the connection from those processes to scientific laws and conclusions.

The interaction of the activities with each other and with the content of GCC/GW was an integral component of the gain in understanding of the nature of science. The relative importance of each activity is difficult to de-construct, since an effective explicit nature of science activity (such as the mystery tube activity) is probably rendered more effective when a follow-up activity is used (such as the greenhouse model/elementary activity discussion). The nature of science content of the fossil activity was likewise reinforced by the GEMS *Oobleck* activity, in which students developed the "Laws of Oobleck." The impact of this elementary-level GEMS activity was illustrated when, toward the end of the lesson, a student asked how we could establish laws of Oobleck when we could not be sure Oobleck would always behave that way – we could never know for sure. This was one of those moments when students think through an idea while talking, and this student's remarks were immediately followed by other students saying, "But that's what a law is," while this student herself was saying, "Oh, that's what we mean by 'not proven'; that's what a law is!" The impact of the two activities used in near-sequential instruction was clearly demonstrated. Likewise, in a discussion about elementary science

activities and the need to be critical evaluators of activities used with children, students related the "mystery tube" activity to the greenhouse effect activity/model, and they discussed how models were not meant to be exact replicas of reality. This topic was brought up again in the closing discussion when the various global circulation models were discussed.

Participants made substantial gains in understandings of nature of science as a result of the explicit approach to nature of science instruction in conjunction with the scientific issue. The results of this investigation, therefore, add further support to the growing body of literature indicating the necessity of an explicit approach to nature of science instruction (Abd-El-Khalick, & Kishfe, 2000; Bell, Abd-El-Khalick, & Lederman, 1998; Bell et al., 2000; Dickinson, Abd-El-Khalick, & Lederman, in press; Shapiro, 1996; Bell, Blair, Lederman, & Crawford, 1999). Certainly, instructional activities must be consistent with currently accepted views of the nature of science, but consistency alone is not enough. If students are to learn specific aspects of the scientific enterprise, the teacher must provide a rich set of learning experiences that addresses the target understandings explicitly. In this study, such learning experiences, combined with explicit discussions about specific aspects of the nature of science and how these related to a real-world controversy, resulted in substantial gains.

While the explicit approach resulted in gains in understanding with these elementary preservice teachers, the research base for the explicit approach would benefit from further studies. For example, secondary preservice science teachers might respond differently to such instruction, given their more substantial backgrounds in science. Other controversial topics, such as genetic manipulation, cloning, nuclear energy, and evolution, lend themselves to further investigations. Also, it is important to extend this line of research into the classroom to see

whether elementary preservice teachers who benefit from explicit nature of science instruction are able to translate their understandings into classroom instruction.

In the final interviews, some participants in this study discussed their ideas about the influence of this project upon their future teaching. Though the actual impact cannot be gauged until these participants begin their teaching, their comments indicated intent to incorporate these understandings into their teaching, as illustrated in the following comment:

> [Studying GCC/GW and the nature of science] makes you realize that science isn't always exact and so you have a responsibility to teach both sides and all angles of a scientific issue. (Post-1)

Whether in-depth, student-centered coverage of a controversial issue is enough to improve participants' views of the nature of science is a question that the authors plan to explore in the future in an elementary science methods course. We believe that this approach not only has great potential for developing elementary teachers with complete understandings of the nature of science and global climate change, but also makes science more accessible and relevant. As one participant said,

> It makes me want to go back and re-evaluate what I thought I knew and ask more questions. Like, it kind of awakens the scientist inside me . . . (Post-1)

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Appendix A

Assigned Readings About Global Climate Change and the Nature of Science

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Appendix B

Views of Science and Global Climate Change Questionnaire

Instructions

Answer the following questions, using the back of the page if you need more space. Please note that there are no "right" or "wrong" answers to these questions. I am more interested in your views than in your getting the science "right."

1. After scientists have developed a theory (e.g., atomic theory, kinetic molecular theory, cell theory), does the theory ever change? If you believe that scientific theories do not change, explain why and defend your answer with examples. If you believe that theories do change: (a) Explain why. (b) Explain why we bother to teach and learn scientific theories. Defend your answer with examples.

2. Science textbooks often represent the atom as a central nucleus composed of positively charged particles (protons) and neutral particles (neutrons) with negatively charged particles (electrons) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine the structure of the atom?

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

5. In the recent past, astronomers differed greatly in their predictions of the ultimate fate of the universe. Some astronomers believed that the universe is expanding while others believed that it is shrinking; still others believed that the universe is in a static state without any expansion or shrinkage. How were these different conclusions possible if the astronomers were all looking at the same experiments and data?

6. What is the greenhouse effect?

7. How certain are scientists that the Earth is warming at a dangerous rate?

8. Is the greenhouse effect a theory or a law? Explain your answer.

9. Would you support the United States government establishing a program to move towards alternative energy sources (solar, wind, nuclear, hydroelectric) even though it might cost you significantly more for electricity?

CHANGES IN THE PHILOSOPHIES OF TEACHING OF FOUR INTERNS DURING THE INTERNSHIP YEAR

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Teachers act on what they believe to be the best way to teach their classes. These beliefs are the basis for their philosophy of teaching. In most teacher education programs, preservice teachers are asked to formulate a statement of their philosophy of teaching. Usually, this is done before the preservice teacher has a significant amount of field experience and these philosophies of education usually are a rehash of some standard set of philosophies studied in an introductory education course. This research project examines the philosophies of teaching of four preservice science interns at the beginning, middle, and end of a yearlong master's degree internship.

Related Studies

Research literature supports the importance of a philosophy of teaching on how and what is taught in the classroom. According to Cronin-Jones (1990), "teacher perceptions and beliefs play a critical role in the curriculum implementation process" (p. 265). The Salish I study (1997) determined that there was a difference in the beliefs about teaching and learning held for new teachers based on the duration of their student teaching experience. Strahan (1993) noted that for student teachers the contradiction between their experience with classroom practices, the knowledge from course work, and how they subsequently resolve this tension, was essential to their development as

teachers. Gonzalez and Carter (1996) found that cooperating teachers and student teachers interpreted classroom events differently depending on their own theoretical framework. Finally, Jones and Vesilind (1995) found that at the beginning of the student teaching experience that the student teachers were concerned about their performance as a teacher and authority figure. By the middle of their experience the focus of the student teacher shifted toward effectiveness of techniques. By the completion of the experience, "many of the student teachers ended . . . with a renewed focus on developing positive relationships with their students as a way to promote student learning" (Jones and Vesilind, 1995, p. 329). All of these factors contribute to continuous revision of a philosophy of education.

Design and Procedures

This study was conducted with four master's degree science interns (three females and one male) during the yearlong internship that leads to teacher certification. The interns were interviewed for the first time during the summer before the internship began, at the end of the fall semester and at the end of the spring semester. The interviews were audiotaped and transcribed. The interviews were based on series of questions selected from the Salish I Research Project (1997) instrumentation package. The interview questions follow:

Interview Questions for Philosophy of Teaching

1. What do you consider to be the founding principles of teaching? If you had to write a book describing the principles that teaching should be built on, what would those principles be?

2. How do you decide what to teach and what not to teach?

3. How do you decide when to move from one concept to another?

4. What learning in your classroom do you think will be valuable to your students outside the classroom environment?

5. How do you believe your students learn best?

6. How do you know when your students understand a concept?

7. How do you know when learning is occurring, or has occurred in your classroom?

8. How do you think your students come to believe in their minds that they understand something?

9. In what ways do you manipulate the educational environment (classroom, school, etc.) to maximize student understanding?

10. How do you want your students to view science by the end of the school year?

Data Analysis

Responses to the interview questions were broken down into key words and phrases. After being coded by intern, the order of interview, and individually numbered,

all the key words and phrases for all of the interviews were placed in a single group and then categorized by similarities. The key words and phrases were grouped and regrouped until seven aspects were developed from their answers to the questions concerning their philosophies of teaching. These seven aspect categories that emerged are the following:

Aspects of Philosophy of Teaching

1. Interns students' attitudes and dispositions
2. How interns know what students know
3. How interns students learn
4. What interns students can have or know as a result of teaching
5. How interns decide what to teach
6. How and what is taught
7. Classroom environment and climate

The key words were divided into groups by interview order and then further subdivided by intern. A summary of this is displayed in the descriptive and interpretive matrices that compare the aspect category to the intern responses (Tables 1 through 4). The first interview for intern #2 is missing from the first matrix because it was lost.

Table 1

Descriptive Matrix Interview #1

Intern	1	3	4
Aspect			
Attitudes and Dispositions	Feeling good, enjoy, use it	Say cool, enjoy, application	Fun, interesting, relate, apply
How Teachers Know What Students Know	Assessment, explain it to me	Assessments, tests, aha	Test, explain, light going on
How Students Learn	Visual, oral, visual aids	Read text, be active	Remembering, do for themselves
Students Have or Know	Look into other aspects	Use Western reasoning	Problem solving, can't live without it
Decide What to Teach	Frameworks, board policies	Standards, student dependent	State standards, what students want
How and What Is Taught	Content, life skills	Real world, relate subjects	Class discussion, tie together
Classroom Climate and Environment	Honesty, respect	Firm knowledge of subject	Basic knowledge, attention to detail

Table 2

Descriptive Matrix Interview #2

Intern	1	2	3	4
Aspect				
Attitudes and Dispositions	Use it, fun	Interesting, use	Like, intrigued, apply to life	Connect to life
How Teachers Know What Students Know	Use own words	See it in eyes, share it	Assessment, aha look	Tell you, write about
How Students Learn	Did it, hands or	Hands on, ask questions	Hear about, read	Involved, participates
Students Have or Know	Process, limits	Perspective changing	Skepticism, confidence	Think, solve problems, inquire
Decide What to Teach	Frameworks, students	Framework, students	Frameworks, students	Standards, students
How and What Is Taught	Cooperative groups, repetition	Subject variety	Experience it, laboratory	Do something, human aspect

Table 3

Descriptive Matrix Interview #3

Intern 1 2 3 4

Aspect

Attitudes and Dispositions	Exciting, fun, go beyond	Interesting, world view	Skeptical view, apply to life	Science is everywhere
How Teachers Know What Students Know	Ask questions, light bulb	Tell me, test, nonverbally	Aha look, assessment	Test, write, in their eyes
How Students Learn	Senses, doing group work	Variety of ways	Independently work together	Hands on, read, develop schema
Students Have or Know		Process, consider it	Practical, process	Problem solving, science method
Decide What to Teach	Standards, mentor	Standards, students	Standards, students	Standards, students
How and What Is Taught	Content, group work	Group work, variety	Learning styles, group work	Experience, variety
Classroom Climate and Environment	Not book, organizaation	Leading, autonomy	Management, care	

Table 4

Interpretive Matrix of Changes in Philosophy of Teaching

Intern	1	2	3	4
Aspect				
Attitudes and Dispositions	No change	Less emphasis on use	Less emphasis on liking	Less emphasis on liking
How Teachers Know What Students Know	Less emphasis on tests	More focus on test	No change	No change
How Students Learn	Increase in hands on	Increase variety	Increase hands on	No change
Students Have or Know	No comments at end	More focus on process	More focus on use, process	More focus on process
Decide What to Teach	Less emphasis on students	No change	No change	No change
How and What Is Taught	More focus on group	More focus on group	More focus on group	More emphasis on hands on, variety
Classroom Climate and Environment	More focus on management	More focus on independence	More focus on managing	No comments after one

Conclusions

The interviews with four science interns at the start of their internship year, in the middle, and at the end is interpreted as follows. The responses to the interview questions as an aggregate appear to include these aspects as pieces of the interns' philosophy of teaching: attitudes and dispositions of students following instruction; how teachers know what students know; how students learn; what students will have or know as a result of instruction; how interns decide what to teach; how and what is taught; and the classroom climate and environment. The results for each interview are summarized in Tables 1 through 3.

Table 4 summarizes changes in the philosophy of teaching of the four science interns during their internship year. Inspection of Table 4 reveals that Intern #1at the end of her internship year emphasizes hands on activities, group work, and classroom management and places less emphasis on student concerns for deciding what to teach and on tests. Intern #2 at the end of his internship year places more focus on tests, science process, variety of activities, group work, student independence, and less emphasis on students being able to use what they learn. Intern #3 at the end of her internship year emphasizes more hands on activities for students' learning, the process of science and use in students' lives, group work, managing the class, and less emphasis on students liking the course she teaches. Intern #4 at the end of her internship places more focus on the

processes of science, hands on and variety in activities, and less focus on whether the students like her class. Most of the interns did not change in feeling that assessment in all forms was an important piece of the aspect of how teachers know what students know. Another aspect that displayed no change was how they decide what to teach. The interns emphasized that state and national standards should be considered, as well as, the interests of their students.

In conclusion these interns' philosophy of teaching changed due to the influence of the their year long internship experiences. There were changes from the idealistic end of the philosophical continuum to a philosophy of teaching tempered by the realities of classroom life. Their concern for students changed away from liking science and seeing it as fun to more focus on management to accomplish the student oriented goals. For all these students their internship year increased their desire to become a teacher and enabled them to develop a repertoire of teaching techniques.

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From Practice to Theory – Narrowing the Gap: First Year Teachers Emerging from a Constructivist Science Education Program

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First year teachers face a complex and formidable set of challenges. No matter how complete the teacher education experience, many unknowns are encountered in the early days of teaching. The need to appear competent and confident intensifies the challenge. "Implicit in the role of teacher is the notion of being knowledgeable, a notion that contradicts the very essence of being a beginner" (Corcoran, 1981, p. 20). That Corcoran's "transition shock" is still experienced by first year teachers points to the fact that preservice teacher education does not, and possibly cannot, prepare individuals for all the new challenges they will encounter in their teaching.

Intertwined with the issue of transition shock is the fact that learning from experience is inevitable. New teachers tend to be unaware of the complexities of teaching that are hidden from view. Bullough, Knowles, & Crow, (1989) asserted that beginning teachers lack "useful understandings of the contexts in which they will work ...and consistent, grounded, and accurate understandings of themselves as teachers" (p. 231). Where teacher educators have succeeded in narrowing the theory/practice gap, and reducing the transition shock, we should see first year teachers who find their work in teaching to be both effective and fulfilling (Wideen, Mayer-Smith, & Moon, 1998).

Included in current education reform efforts is the development of better ways of helping teachers make the transition into the profession. A much needed and growing area of research seeks feedback on teacher performance during those first few years of teaching practice. Secondary science education programs in particular have been criticized for failing to look

beyond the immediate task of preparing teachers (Anderson & Mitchener, 1994; Sanford, 1988; Zeichner & Tabichnick, 1981). Thus, the main issue that prompts this research is the transition shock that new teachers face in their first year of teaching. More specifically, this research work emerged from an interest in exploring how graduates of a particular preservice program worked through that transition.

The Problem

This study addressed two related problems. The first problem is that traditional, teacher-centered pedagogies dominate current teaching practice despite numerous research-based findings that promote more student-centered, constructivist-based teaching methods (Duckworth, 1987; Fraser, 1994; Tobin, Tippins, & Gallard, 1994.) The second, more specific problem is the "gap" between educational theory and practice. The progressive pedagogies promoted by some teacher education programs are often not implemented once the teachers begin their work in the classroom. There is a need to identify teacher education program designs that produce teachers who fulfill the more progressive "constructivist" referent in their work as science teachers. Constructivism has greatly influenced the field of education and science pedagogy in particular. Advocates of constructivist-based environments call for educational settings that offer opportunities for hands-on, minds-on manipulation of data as individuals and groups build knowledge. The benefits of constructivist-based learning environments for academic and social growth have been documented (Duckworth, 1987; Fraser, 1994; Tobin et al., 1994). Nevertheless, traditional teacher-centered classrooms that restrict students' involvement in the learning process have been far more prevalent than student-centered, constructivist classrooms (Kaufman, 1996).

A decade of research in secondary science classrooms led Gallagher (1993) to present the following summary of current pedagogical trends:

> Lecture-discussion, with occasional demonstration is most common in secondary science classes. In both of these cases, the teacher does most of the talking while students are passive recipients. Movies, the chalkboard, and overhead projectors add a visual dimension. These whole class methods of presentation typically are coupled with individual written work by students. In spite of much talk about "hands-on" approaches to science, they occur rather infrequently in most secondary science classes. Further, hands-on activities usually are designed to help students with acquisition, rather than to assist with integration or application of knowledge. (p. 184)

Lecture, demonstrations, and laboratory activities are the pedagogical staples of those science teachers whose primary focus is "covering the material". Teachers operating under this dominant paradigm present information, provide experiences for validation, test for acquisition of content, and then move on to the next topic. Teachers operating under a constructivist referent would argue that presentation is only one part of the teaching process. Their teaching would incorporate opportunities for students to draw upon prior experience so they might integrate the new information with what they already know. Students learning in a constructivist environment would have opportunities for collaboration and discussion of science concepts with their peers. Teaching strategies that help students to make broad connections between prior knowledge and further questions, thus applying the new knowledge beyond the classroom, characterize instruction based on a constructivist orientation. Though "constructivism" is an epistemology, the term also serves as a referent or frequently used label for teaching practices that place the learner (and learning process) at the center of instruction. Assuming that knowledge cannot be transmitted in the same form from one mind to another, "constructivist teaching" allows the learner to draw upon prior knowledge and build conceptual understanding of new phenomena through thoughtful activity.

In this study, the first author investigated the on-the-job development of first year teachers who worked in different settings but shared a common experience of a constructivist-based teacher education program. Specifically, I investigated the pedagogical perspectives and implicit theories that emerged by the end of the first year of teaching. Such studies are needed to help us understand how the current climate in schools, individual teacher biographies, and elements of preservice teacher education contribute to the type of teaching that goes on in schools.

Two questions guided this study:

1. After completing a constructivist-based preservice science education program, what pedagogical perspectives were apparent among participants during their first year of teaching?

2. What was the relation between the first year teachers' perception of their teaching practice, their implicit theories of teaching, and the pedagogical thrust of the preservice program?

Assuming that a continuum rather than a simple dichotomy is a more appropriate conception of teacher practice, "pedagogical perspectives" afforded a more open-ended approach to the question of how participants taught. The second question referred to the participant's "perception of practice" or "implicit theory" of what they found to be effective in their teaching practice. Implicit theories are "the ideas about instruction that teachers develop from their personal experience and practical knowledge" (Charlesworth, Hart, Burts, Thomasson, & Mosley, 1993, p. 256). The goal of the study was to elicit a detailed description of teaching practice and personal theories, then through inductive analysis, relate these descriptions to the design of the preservice program.

An alternative, master's level science education program which is part of a larger program known as Teacher Education Environments in Mathematics and Science (TEEMS) has provided the preservice context for this study. As graduates of the TEEMS program began their

work as science teachers, they encountered a variety of contextual influences at their school. We were interested in exploring how their teaching practice was consistent or inconsistent with the pedagogical thrust of the preservice program as well as contextual dynamics of the schools in which they worked.

The TEEMS Program

TEEMS began in 1994 as a nontraditional approach to mathematics and science teacher education at Georgia State University (GSU) in Atlanta, Georgia. It originated in 1993 as an alternative preparation program in science and mathematics education (Hassard, Rawlings & Giesel, 1993). Applicants to the program must hold at least a bachelor's degree in science or engineering or the equivalent. Students are admitted to TEEMS in the spring of each year. They then progress through a four-term course of study.

The underlying framework for the TEEMS Project is constructivist theory, which asserts that human beings construct knowledge through acting on their environment and interacting with other humans. These ideas were based on the work of Piaget (1973), Vygotsky (1978) and von Glasersfeld (1991). The constructivist model of teacher education is evidenced by the TEEMS program design that guides student learning about classroom management, cooperative learning, lesson planning, and the ways that adolescents learn science in the context of schools. The TEEMS environment is intended to be interactive, reflective, and based on inquiry. Operating from an acceptance of research assertions that such preconceptions are resistant to change using traditional methods (Whal, Weinhart, & Huber, 1984), the project directors designed TEEMS within an active learning model in which students continually work within a cadre of peers. This cadre or cohort is central to the design of TEEMS.

Through collaborative groups and reflective activities, TEEMS students experience science pedagogy and instructional planning through microteaching experiences under the guidance of university professors and participate in school-based internships under the guidance of middle and secondary school mentor teachers. The TEEMS experiences were based on sequenced phases. These phases involved (a) a summer institute characterized by a series of reflective teaching experiences that became increasingly demanding, (b) a fall semester internship in the middle school, and (c) a spring semester internship in the high school. Throughout these experiences, students monitored their beliefs and considered their preconceptions about teaching as they participated in teaching experiences and reflected on educational theory.

The TEEMS Curriculum

The TEEMS science education program begins each June with a Summer Pedagogical Institute and progresses through its internship phase, culminating in a portfolio presentation and completion of coursework the following summer. The curriculum, goals, and experiences are detailed in Table 1. This four-term program emphasized the following pedagogical practices: (a) term 1, Summer Pedagogical Institute focusing on preconceptions of teaching and induction into a constructivist approach to pedagogy; (b) term 2, a fall semester experience to develop pedagogical content knowledge in the context of middle school students and teachers; (c) term 3, a spring semester experience to develop pedagogical content knowledge in the context of high school students and teachers; and (d) term 4, a second summer experience of reflection, portfolio presentation and employment acquisition.

Table 1

The TEEMS Curriculum

Term	Curriculum	Focus	Goals	Internship & Teaching Experiences
Term 1: Summer 1998	• TEEMS Summer Institute • Education or Science Coursework	Reconnaissance of Science Teaching Introduction to inquiry-based teaching and learning	Connect preconceptions of teaching and learning to a constructivist approach to pedagogy	Reflective teaching episodes Microteaching Team teaching in a summer science camp
Term 2: Fall Semester 1998	Theory and Pedagogy of Science Teaching Middle School Internship Education and/or Science coursework	Development of pedagogical strategies in the context of middle school classrooms Reflective analysis of one's ability to plan, implement, and evaluate teaching and learning	Construct knowledge of teaching through concrete experiences, reflection and discussion	School-based experiences in a middle school, as well as field trips, and special projects with middle school students and teachers Working relationship with a mentor teacher
Term 3: Spring Semester 1999	Theory and Pedagogy of Science Teaching High School Internship Education and/or Science coursework	Further development of pedagogical strategies in the context of a high school Reflective analysis of one's ability to plan, implement, and evaluate teaching and learning	Construct knowledge of teaching through concrete experiences, reflection and discussion	Apprenticeship in a high school involving special projects Working relationship with a mentor teacher
Term 4: Summer 1999	Portfolio Presentation & Assessment Education and/or Science coursework	Assessment of one's progress as a TEEMS student Presentation of Portfolio in a public setting	Use a professional portfolio to reflect on one's growth and development as a teacher	Portfolio assessment and presentation

The role of the teacher educators in the TEEMS program was one of "facilitator" or "guide" (Richardson, 1999; Rogers, 1984). A consistent pattern in the teaching method of the TEEMS professors was to involve TEEMS students in hands-on activities followed by

thoughtful discussions. In other words, the directors of the TEEMS program would not characterize their work in teaching teachers as one which involved the direct transmission of knowledge. Instead, they favored the "facilitator" metaphor, which positioned them as knowledgeable mediators of experiences intended to help students build knowledge about teaching.

Review of Literature

A critical analysis of 93 empirical studies illuminates what is currently known about how people learn to teach (Wideen et al., 1998). Program designs that build upon the beliefs of the beginning teacher are now considered to be an approach more productive than transmitting theory to be applied by novice teachers in their practice. The most common recommendation made in the learning to teach literature is that beginning teachers need to examine their prior beliefs about teaching as an essential first step of induction to the profession. Working with a cohort group in a program which involves "a systematic long-term message that provides some guidance and direction for personal development" further characterizes supportive teacher education programs (Graber, 1996, p. 455).

Such programs seek to move away from an application of theory model in favor of more reflective approaches. Instead of the traditional "student-teaching" experience which culminates the teacher education program and in which the novice is to apply theory, the more reflective approach places internship teaching experiences in conjunction with ongoing interaction with professors and peers in the teacher education program. This represents a constructivist philosophy of teacher education described by Calderhead & Robson (1991):

> Many of these attempts can be characterized by an emphasis on reflective teaching, implying that teacher education is conceptualized as an ongoing

> process of experiencing practical teaching and learning situations, reflecting on them under the guidance of an expert, and developing one's own insights into teaching through the interaction between personal reflection and theoretical notions offered by the expert. (p. 2)

Constructivist teacher education programs may provide a different developmental outcome than Lortie (1975) described. Under his interpretation of teacher socialization, new teachers tend to emulate the rather conservative pedagogies that have dominated their "apprenticeship of observation." Korthagen & Kessels (1999) describe constructivist teacher education as "realistic teacher education" and assert that such programs eliminate the gap between theory and practice. They describe this approach as one that

> goes from practice to theory. An interesting aspect is that the gap between theory and practice disappears, although it is better to say that the education process itself does not create it, as in the case in the traditional approach. In cognitive psychological terms one can say that the intended learning processes start from 'situated knowledge', developed in the interaction of the learners with the problem situations, and that the concrete situations remain the reference points during the learning process. (p. 7)

It is with little argument that objectivist perspectives have been used to make sense of schooling in the past (Dana & Davis, 1993). The mental images of what schools based on objectivism look like are common to us all, because that is how the vast majority of schools have been run for generations. As one begins to consider constructivist alternatives to traditional schooling, the need for examples of "constructivist classrooms" often emerges. Cobb (1994) reminded us that "constructivist teaching" is a misnomer, for "the various versions of constructivism do not constitute axiomatic foundations from which to deduce pedagogical principles" (p. 4). Cobb explained that constructivism should be thought of as a general orienting framework from which to develop instructional approaches and address pedagogical issues. In other words, constructivism is a theory of knowing and not a method of teaching. This

is why Tobin (1993) has labeled constructivism a referent (and not a method) for science teaching.

A constructivist approach requires a realization that individuals and groups negotiate meaning. Wheatley (1993) emphasized the need to allow students to discuss concepts with peers and teachers, as opposed to just listening to explanations. The emphasis on cooperative learning is largely in response to this need, and offers a tangible method for moving toward more student-centered instruction. Linn and Burbules (1993) concurred that promoting the motivation to learn is more important than holding to particular methods, and thus, cooperative learning should not be utilized just because it is currently popular. Educators must understand the goal behind learning activities, and design opportunities for students to learn in meaningful, thoughtful ways. Along the same line of argument, Roth (1993) asserted that it is not the method that is of importance, but the focus on learning that matters most. He warned educators that they must continually consider the individual needs of students and utilize a varied repertoire of methods, using professional judgment in guiding student learning. Constructivist theory also promotes the design of learning environments that are conducive to nurturing students' confidence in their own ideas and their ability to develop viable concept formulations (Jakubowski, 1993).

The manner in which constructivist theory influences teaching practice is applied to both the practice of secondary teachers and the design of teacher education programs. To help teachers adopt teaching strategies that promote active learning, teacher educators should help teachers understand learning from a constructivist perspective (Dana & Davis, 1993.) Traditional teacher education, which tries to tell teachers what to do, often fails because they fail to engage teachers in the activity of examining their beliefs about learning. Shaw and Etchberger (1993) argued that

> for successful and positive change to occur, teachers need to be perturbed, they need to be committed to do something about the perturbation, they need to establish a vision of what they would like to see in their classrooms, they need to develop a plan to implement this vision, and they need support to carry out their vision. (p. 265)

Peterman (1993) addressed the issue that the vast majority of staff development institutes focus chiefly on the implementation of classroom procedures. She recommended that in working with new teachers, staff development directed at pedagogy should help teachers to make explicit their implicit 'core' beliefs and personal theories about classroom practice and assist them in reconstructing beliefs about learning and teaching. The bottom line, whether teaching teachers or secondary students, is that constructivist theory motivates educators to allow for the individualistic process of learning, a process that ties to both prior experience and social interaction.

In Best Practice, New Standards for Teaching and Learning in America's Schools (Zemelman, Daniels, & Hyde, 1998), qualities of best practice in the various disciplines was presented. In the area of science teaching, this work encouraged educators to "make science learning experiential instead of lecture-oriented, cognitive and constructivist rather than focused only on facts and formulas, social and collaborative rather than isolating students from one another" (p. 110). Using the Benchmarks for Science Literacy (1993) and the National Science Education Standards (1996) as reference points, Zemelman et al. (1998) asserted the following imperatives of best practice in science teaching: (a) students need opportunities to explore the significance of science in their lives; science study should involve doing science, that is, questioning and discovering, not just covering the material; (b) effective inquiry involves a series of steps that build students' investigation skills (questioning, observing, organizing data, explanation, reflection, taking action); (c) meaningful science study will aim to develop thinking,

problem solving, and attitudes of curiosity, healthy skepticism, and openness to modifying explanations; (d) science education can build a knowledge base focused on essential concepts rather than disconnected topics or bits of information; (e) students should explore fewer topics in depth, not skim many superficially; (f) students grow out of misconceptions and naïve theories only by actively engaging in investigation; (g) learning science means integrating reading, writing, speaking, and mathematics; (h) students need to consider issues of application of science and technology (Zemelman et al., 1998, pp. 111-120). In this account, good science teaching involves facilitation, collaborative group work, and a limited judicious use of information giving (Zemelman et al., 1998). Though these best-practice recommendations could be worked toward in an objectivist "discovery" approach, the interactive, experiential, and collaborative emphasis of these recommendations is very much in line with the constructivist referent in science education. The science education reform agenda is based on this pedagogical view.

Methods

Our investigative approach has been influenced by the conviction that educational research can and should improve the human condition. Kozaitis (1998) asserted, "The late 20th century has witnessed the rise of anthropological praxis-- intellectually mediated, ethically sound, and socially responsible work (p. 11). According to this concept, a humanitarian ethic should drive the research process. The three conditions of anthropological praxis hold that social research methods must be well thought out (intellectually mediated), they must not harm or take advantage of the researched (ethically sound), and the research should "give something back" to the individuals or groups participating in the research (socially responsible). Research as praxis is characterized as a synthesis of intellectualism, pragmatism, and compassion in organized efforts to understand, and to serve humanity. . As Gallagher (1991) explained, "Interpretive

research not only helps researchers learn about teachers thoughts, beliefs and values, but it illuminates them for the teachers themselves, thus allowing teachers to become more reflective about their own work" (p. 7).

Selection of Participants

Four of the 19 members of the 1998-1999 TEEMS cohort were selected for this study. The choice of participants evolved from a process of interaction with the participants during the preservice program. We chose participants with which we had good rapport and to whom we had access during the first year of practice. The participants chosen were considered to be good interview candidates, as indicated in pilot study work. Students who had shown willingness to maintain detailed lesson plans and consistent journal entries were chosen. The individuals selected for study met these criteria, and Morse's (1994) definition of a good informant, as "one who has the knowledge and experience the researcher requires, has the ability to reflect, is articulate, has the time to be interviewed, and is willing to participate in the study" (p. 228). Each of the participants in the study was experiencing their first year as science teachers in the same large metropolitan school district. This school district employed approximately 7,500 classroom teachers who served more than 90,400 students in grades K-12. The school system is one of the fastest growing districts in its state, adding an average of 2,700 students per year. The four participants worked in three different public schools. Two females taught ninth grade Physical Science in an upper-middle class suburban school. A third female taught tenth grade Biology in a high school that served students from lower socioeconomic status. The fourth participant was a male who taught Physical Science, Physics and Astronomy in a middle class suburban high school.

Data Sources

Interviews, reflective writing, and artifacts from teaching formed the sets of data collected in this study. We followed Seidman's (1998) protocol for in-depth, semi-structured interviewing. This interview method involved a series of three separate meetings with each participant. Each interview had a different purpose, and when considered in a series, each interview provided details that formed the basis of the next meeting. The first interview established the context of each participant's teaching experience. This involved inquiry into details about "settling into" the teaching position, and also included aspects of personal history that related to their work in teaching. The second interview probed the details of teaching experience. To do this, we focused on the concrete details of the participants' teaching experience. Participants were asked to talk about their relationships with students, faculty, and administrators in the school in order to place their experience in the context of the social setting. Participants were asked to reconstruct details of what they do in their teaching work. In the final interview, participants were asked to discuss the personal meaning of their experience. The meaning referred to here was the intellectual connection between learning to teach in the first year and experiences that preceded this practice. Questions of implicit theory, or "learning-from-experience" were thus used in the third interview in relation to what was revealed in prior interviews.

This three-interview structure involved spacing each interview one week apart. This "allowed time for participants to mull over the preceding interview but not enough time to lose the connection between the two" (Seidman, 1998, p. 15). Each participant's interview series was conducted over a three-week period. Each interview required sixty to ninety minutes. I conducted only one interview per week, to allow myself the time to transcribe the interviews as

the data was collected. All four participants progressed through the interview series during a 12-week period of time between early February and late-April, 2000. The data collection schedule is given in Table 2.

All interviews were tape recorded and transcribed for analysis. The tape-recorder allowed ua to capture the interview in a detailed manner. When I requested permission to tape-record the interviews, each participant agreed without reservation. Even while using the tape recorder, notes were jotted during the interview as a back-up data source, should the tape recorder fail. These jotted notes have proven in the past to be a helpful guide in monitoring the progress of the interview. The interview guide is posted as Appendix A at http://scied.gsu.edu/Hassard/dias-aets01.html.

Additional data sources included journal entries and documents generated by participants in their teaching work. The teachers in this study were asked to keep a weekly journal in which they wrote out reflections on what they were learning about teaching during their first year. Written documents are commonly analyzed in qualitative studies for salient excerpts and passages (Bogdan & Biklen, 1998). The study utilized reflective writings not unlike personal diaries. They were also "assigned" three questions to respond to in their journals. These questions were assigned on a one per week basis during the 3-week interview protocol. The three specific questions assigned as journal entries are provided in Appendix B at the site given above. Teaching artifacts or documents of teaching work were collected after the final interview. We asked each participant to think about his or her first year teaching practice and pull from his or her teaching units two examples of "teaching that worked". Hodder (1994) asserted that such material traces of behavior provide different insights from that provided by questioning the participants, for often "what people say" is different from "what people do." Thus, analysis of

teaching artifacts representative of first year practice validated the discussion of practice contained in the interview

Table 2

Data Collection Schedule

Meeting Number	Interview Theme	Journal Assignment	Comments
1	Establishing context of participant's teaching experience.	What did you learn about teaching from the first semester?	
2	Reconstructing details of teaching experience in context.	What did you learn from a lesson that "didn't work"?	Collected journal assignment #1; returned interview #1 transcript
3	Reflecting on the meaning that the teaching experiences holds for participant	What is your theory or explanation of "what works" in teaching science?	Collected journal assignment #2; collected interview #1 transcript with comments/ corrections; returned interview #2 transcript.
4	No Interview	No Journal Assignment	Collected journal assignment #3; collected interview #2 transcript with comments/ corrections; returned interview #3 transcript.
5	No Interview	No Journal Assignment	Collected interview #3 transcript with comments/ corrections; collected artifacts/ documents; gave thank you gift

and journal data (Bogdan & Biklen, 1998).

Analysis

Qualitative analysis is an inductive process. Through thematic analysis, categories and patterns emerged from the data (Janesick, 1994; Patton, 1990). Following each interview, the tape-recorded conversations were transcribed. In addition to producing a data-base for coding, the transcription process allows the researcher to consider the details of the previous interview and focus subsequent interviews to probe emerging patterns (Maxwell, 1998).

Analysis of the interview transcripts involved a process of systematically reading and arranging the data in order for the participant's discussion of their teaching experiences to be presented. As defined by Bogdan and Biklen (1998), analysis of qualitative data involves "working with data, organizing them, breaking them into manageable units, synthesizing them, searching for patterns, discovering what is important and what is to be learned, and deciding what you will tell others" (p. 157). The development of codes, themes, and categories was guided by Strauss and Corbin's (1990) method. A flow chart summarizing my methods of analysis is given as Figure 1.

The Participants and Their Schools

Tina Tutt, Cheryl Jones, Woodside School

The Woodside School was unique in its student composition. It was an eighth and ninth grade public school established for the 1998-1999 and 1999-2000 school years. The school operated (in an area of rapid suburban growth) in a building that formerly housed a middle school. The adjacent high school, built to operate at an enrollment of 2200 students, was

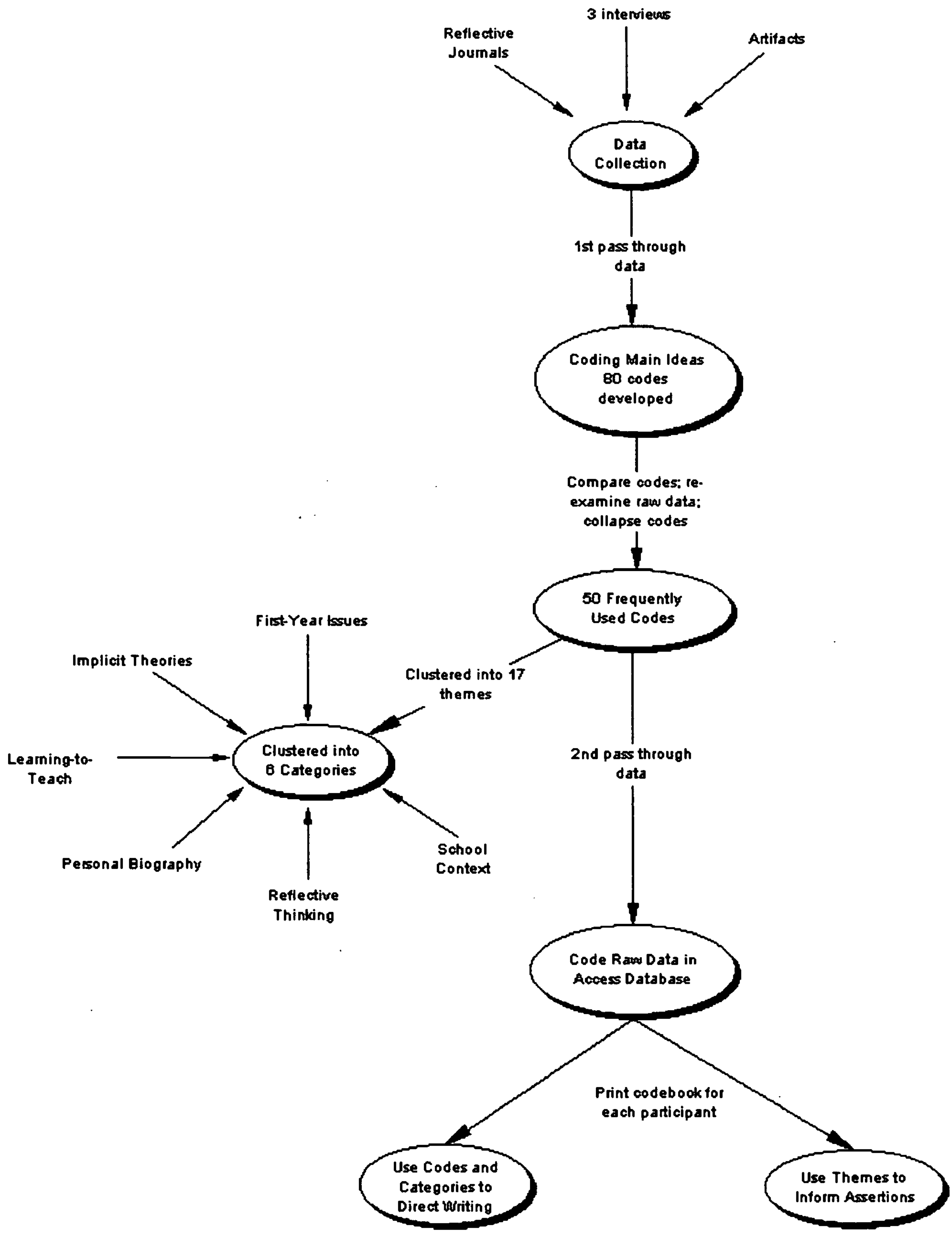

Figure 1. Flowchart of Analysis Methods

overcrowded with nearly 3000 students during the 1997-1998 school year. To deal with this overcrowding, the high school enrollment was reduced to include only the 10th-12th grades, and Woodside School was devised as an eighth and ninth grade facility to operate during the period of time in which a new high school would be constructed and staffed.

Tina Tutt and Cheryl Jones were two of 83 teachers at Woodside School. They both taught ninth grade Physical Science. At Woodside, the eighth and ninth grade classes consisted of 1,365 students. This school was in an upper-middle class suburban area of the county. Since the Woodside School was not a high school, I cannot make comparison with the other two schools regarding percentage of graduates attending Georgia public colleges. Even the dropout rate data, at 0.2%, should be considered in light of the fact that this is a unique school consisting of only eighth and ninth graders. The Woodside School was the least diverse of the three schools in this study, consisting of 4.5% African American, 1.5% Asian, 92.4% European American and 0.8% Hispanic students. At Woodside, 2.6% of the students qualified to receive free/reduced lunches. Cheryl Jones and Tina Tutt both taught ninth grade Physical Science at this school.

Tina earned her bachelor's degree in marine biology and had worked for about a year and a half as a lab technician when she decided to apply to the TEEMS program. She had enjoyed the lab work during her undergraduate studies, but explained that after only one year of work as an environmental lab technician and eight months in a microbiology lab, she found the "everyday routine to be very boring." She explained that when she graduated from high school she made a promise to herself that no matter what she chose as a career, she would always try to make a difference in the lives of others. Tina believed that becoming a teacher would be the best possible way to achieve this goal.

While Tina was in college, she spent a summer working at the New England Science Center as a counselor for an environmental science camp. This was the first opportunity that Tina had with teaching children. She described an initial nervousness that faded away as she realized how interested the students were in what she was able to teach them. The camp was a perfect setting for Tina to teach children "amazing things about the environment." It was a fun and fulfilling experience for Tina, and one that led her to the TEEMS program.

Cheryl, like Tina and Laura, came into teaching after a brief period of work as a lab technician. Cheryl worked in an air testing lab and an organic chemistry lab for one year. Like Ed Kilmer, Cheryl planned to become an educator after completing her undergraduate studies. During her brief time in laboratory work, Cheryl maintained her intention to pursue a master's degree in education.

As a young girl, Cheryl was inspired by a fourth grade teacher who treated everyone as an individual and made special efforts to show that she cared. Like the teacher who inspired her, Cheryl wanted to teach each of her students in such a way that they felt good about their learning, and that they were an important part of the class. She explained, "School is more than memorizing equations and working word problems. It's one of the places where young people find their identity, and teachers are an important part of that process."

During her year as a lab technician, Cheryl tutored students after school. After working in the lab all day she looked forward to working with children. She enjoyed the rewards of helping students to master skills they were unable to grasp in class. Cheryl seemed committed to a career in education, for she spoke of a desire to eventually earn a Ph.D. in science education.

<u>Laura Cane, Overton High School</u>

Laura accepted a science teaching position at Overton High School. She was one of 102 teachers in this four-year public high school that drew students of lower socioeconomic status. Overton enrolled 1,672 students and was among the oldest high schools in the district. During her first year at Overton High, Laura taught 10th grade biology, which was her favorite content area in science.

When Laura was younger, she considered becoming a teacher, but that possibility did not return to the forefront of her thinking until a few years after earning her bachelor's degree in biology. After working in pharmaceutical administration for a couple of years, Ms. Cane began considering a career in science teaching. A coworker at the pharmaceutical lab who was pursuing her teaching credentials was highly influential in Laura's interest in teaching. "It just seemed like that was what I was suppose to do," Laura explained. She further elaborated that she remembered feeling that she should teach to "turn kids on to science, and make them realize it's not some foreign language, but that it's a part of your everyday life. It just seemed like that was what I was suppose to do."

Laura entered the TEEMS program with a desire to have the type of classroom that promoted learning and gave the students something to look forward to during their day. Laura was concerned by reports that claimed our nation's schools were not providing students with a thorough education, and that we were losing our competitive edge with other developed countries. She wanted her students to be prepared for what awaited them after high school, whether it was a job, college, or vocational school.

Overton High School contained a diverse student population consisting of 38.7% African American, 3.5% Asian, 49.1% European American and 7.2% Hispanic students. The dropout rate for grades 9-12 was 7.1% at Overton, above the system average of 3.7%. At Overton High, 278

students qualified to receive free/reduced lunches, which at 16.6% is slightly below the system average of 17.8%.

Ed Kilmer, Willers High School

Ed Kilmer had chosen to teach science due to an inspiring father, who taught science and mathematics in Iraq. "To be a teacher, a person must have patience, knowledge, and caring for students," Ed wrote as he recalled the saying often repeated by his father. Ed explained that with 12 siblings, "patience was an essential part of everyday life." Several of his family members were teachers in his homeland. Soon after Ed moved to the United States he decided to pursue a career in science education. Ed asserted that patience is very important in working with teenagers, explaining that "good instruction requires a teacher to explain a concept over and over from different perspectives until each student comprehends the information."

Elaborating on his ethic of care, Ed explained that when his father died during his junior year of high school, he accepted the responsibility of caring for his sisters, talking to their teachers, and helping them with their schoolwork. "This type of caring I learned from experience. To truly care for someone you must do it out of your heart and not expect anything in return. A good teacher should care about their students, whether they need help with their school work or in other parts of their lives."

In Ed's view, knowledge is the final component of good teaching. His Bachelor of Science degree was in biology, and he has extended his studies beyond life science, studying a variety of science disciplines from geology to physics and astronomy. Ed recalled his father's love for teaching young people and referred to his own growth as a science student as he asserted, "Becoming a science teacher is in my blood. Now it's my turn to begin helping students."

Ed began his work as a science educator by teaching Astronomy at Willers High School. Willers was a four-year public high school. Mr. Kilmer was one of 97 teachers in this middle class suburban high school with an enrollment of 1,784 students. Willers High School contains a diverse student population consisting of 27.2% African American, 7.9% Asian, 57.4% European American and 5.4% Hispanic students. The dropout rate for grades 9-12 at Willers is 1.9%, below the system average of 3.7%. Ninety-four students at Willers qualified to receive free/reduced lunches, which at 5.3% is below the system average of 17.8%.

Results

Four themes or patterns in the data directed the presentation of the pedagogical perspective and implicit theories of teaching for Tina, Cheryl, Laura, and Ed. These themes were: "challenges to teaching", "first-year surprises", "teaching methods", and "knowledge for teaching". Though most of the participants' discussion presented here draws from common codes within these themes, there were both obvious and subtle differences in each participant's discussion within a common code.

For example, each participant spoke of classroom management, which was categorized as "first-year issues" and classified under the theme of "challenges to teaching." However, what they said about classroom management varied both in the frequency and substance of response. Tina described only minor classroom management issues, and when she did, they were in the context of the meeting student needs code. Cheryl worked at the same school as Tina, but gave multiple references to classroom management issues, especially from her first semester. Her discussion of this issue centered on her belief that her "laid-back" or "nice" approach needed to be modified. Where Tina related her management issue to meeting student needs, Cheryl related

hers to her own need to learn management techniques from the first semester experience. Laura's experience at Overton High also revealed classroom management issues, however hers seemed a bit more profound than those of Tina and definitely less pronounced than that of Cheryl. Laura, like Cheryl, said that she learned how to better manage student behavior through the experience of teaching; however, she also emphasized her efforts to promote positive student interactions. Ed had some classroom management issues as well, but he interpreted these in terms of the inaccurate expectations that his Astronomy students had for his class. As Ed described it, an equally strong challenge to teaching was student's lack of adequate prior knowledge of math and science.

If we could bring together all of the commonalities of the four participants view of teaching, what would it look like? What follows is a synthesis of the pedagogical perspectives and implicit theories of all four participants.

Patterns of Pedagogy

Throughout the journal and interview transcripts and in response to various questions, we found seven patterns of pedagogy that were common to the four participants. In presenting the teaching methods emphasized by the four participants, we are highlighting similar views of teaching held by each participant and permeating the data.

Grouping Strategies

A strong pattern in the data was seen in the participants' frequent reference to their use of grouping strategies. Of all the teaching methods described by the participants, collaborative grouping of students to promote individual engagement and cooperative learning was the most common pedagogical element. Tina emphasized the way one student in the group might understand a science concept better than others and serve as a peer-tutor, thus making the

learning environment more productive. Cheryl spoke of the way student groups built community in her classroom. She persisted in the use of grouping strategies despite the challenges posed by classroom management. Laura exhibited an adaptable approach to grouping. By holding students accountable through closely monitoring their progress in groups she was able to find grouping strategies to be an effective teaching method, to the disbelief of colleagues in her department. Ed expressed less emphasis on grouping strategies. When he discussed student groupings it was for the purpose of increasing the efficiency of handling materials in lab settings.

Students Help Teach

All four participants in the study described a teaching method that we will call "students help teach." In this method, students are given science-related information, (usually in the form of text materials), and are then asked to work in small groups to interpret and present the concepts. According to their description, this served three functions. First, it was a type of "divide and conquer" technique, through which small sections of the course content were divided up among the class and then described by students in brief presentations. Second, at times students were asked to give their interpretation and explanation of a science concept in the hope that their view of the concept would help others understand. Tina and Cheryl both spoke of this. Third, the participants emphasized that having the students present science concepts made it more interesting for the learners. In their view, the students liked hearing from each other instead of the teacher being the only person presenting concepts. Cheryl and Ed made fewer references to this technique. Cheryl described a "Teacher for a Day" project that she considered one of her most effective lessons. Ed referred to this technique only once. He had his Physical Science students present information on a chemical element.

Similar Format of Daily Instructional Strategy

The third pattern in the participants' pedagogical perspective involved a close similarity in the format typifying the daily lesson plan. They each described their lessons as consistently featuring an early phase in which they present information, followed by a phase in which their students did either a hands-on activity or guided practice worksheet. Three participants said that the "notes" phase was structured and interactive, taking on the form of a discussion. Ed referred to this phase as lecture, and he was also the only participant to emphasize consistent use of scientific demonstrations. The activity phase involved opportunities for students to apply the concept described in the initial phase. Participants used the terms "lab" and "group work" to describe what the students were doing in the activity phase. It was less common for the teachers to place the activity ahead of the explanation, although each of them described different situations in which they had utilized this inquiry-approach. These teachers found it difficult to find or develop a high number of activities that could promote "learning by discovery". In contrast, they found it rather easy to implement a variety of hands-on activities that reinforced their explanation of concepts.

Of the four participants, Cheryl gave the fewest descriptions of her teaching format fitting into a typical daily sequence. The other three participants said that they always started their lessons with a brief "warm up" activity intended to engage the students at the beginning of class. All four participants used a posted "agenda" to inform the students of the sequence of events in the class period. This was a common aspect of their meetings in the TEEMS program. The "warm-up" activity described by Tina, Laura, and Ed are similar to the "invitation" phase of the constructivist teaching model emphasized in TEEMS. Other elements in the daily instructional strategy deviated from the constructivist model. This model describes the sequence of "invitation" followed by "exploration," then "explanation," and ending with "taking action."

This sequence places student activity before the discussion or explanation of science concepts. The emphasis on "notes" before "activity" in the pedagogical perspectives is a reversal of order counter to the constructivist-teaching model. The frequent references to collaborative groupings are, however, in line with the ideas of social constructivism. The "taking action' phase of the constructivist teaching model was not mentioned as a part of the participant's conception of a typical daily instructional strategy. They did, however, describe student project work, which extended beyond the parameters of a single day.

Each participant spoke of the importance of breaking the ninety-minute block of class time into a variety of lesson elements. Perhaps block scheduling itself led these teachers to follow the strategy of breaking up the lesson into an information phase and an activity phase. They each asserted that they never "presented information" the entire period because they were certain that this would not hold the students' attention.

Promoting Engagement

Each participant in the study expressed a strong aversion to "boring" the students. They each said that they frequently used hands-on activities to engage the students and help them find science to be fun and interesting. For Tina, an "honest, open dialogue" promoted student questioning and engagement. Cheryl planned lessons by first considering "How are the students going to get this?" She tried to vary the instructional strategies in ways that matched teaching method to subject matter. Laura said that she just felt like an ineffective teacher when the students looked bored, and that she had to use frequent activities to hold her students attention. Ed valued an engaging classroom environment because he believed it was important to keep his honors Physical Science students "on the science track" and employed daily activities to win over his difficult Astronomy students.

Review Strategies

Each of the participants described the use of daily review in the form of questions directed to the whole class. Laura and Ed described well-developed review games that they used with their students. These followed game show and board game formats. They used these games because they believed the students enjoyed them and that the review was necessary to help their students do well on tests.

Assessment by Daily Monitoring and Traditional Tests

According to the accounts given in our interviews, all participants monitored student progress through the use of observations, whole group questioning, and quizzes. Each of the teachers emphasized the use of traditional end-of-unit tests as formal assessment instruments. These tests were always described as "objective" in format, consisting of multiple choice, fill-in-the-blank, and short answer items. The participants ascribed to traditional tests as a primary means of formal assessment for reasons of efficiency and objectivity.

Restructuring Content Knowledge

Each of the teachers involved in this study discussed the belief that they needed to continue to find new ways of explaining science concepts and involving students in activities that foster learning. They each described a lesson planning process that involved a restructuring of their science content knowledge. Laura emphasized the difference between science study for the university major and science study for the secondary student in describing her belief that she had to explain biology concepts in ways to which her students could relate. Tina, Cheryl, and Ed each spoke of teaching science concepts in multiple ways to help as many students learn as possible. They each described a process of preparing to teach that was characterized by a search for activities and alternative explanations from various sources (textbooks, Internet, other

teachers). This demonstrates that to them, teaching was more than the telling of ideas in the same way to each class. These four teachers were involved in a process of restructuring their science content knowledge for pedagogical intentions. In their teaching practice they were developing pedagogical content knowledge.

Implicit Theories of Teaching, and the Pedagogical Thrust of the TEEMS Program

The second guiding question of this study sought the relation between the participants' view of teaching methods, their explanation of "what worked" in their teaching practice, and the predominant science teaching methods promoted in the TEEMS program. In the coded interview and journal data, there were no striking differences between the pedagogical perspectives and implicit theories for the four participants. Thus, the main focus of my discussion here turns to the relation between the pedagogical thrust of the TEEMS program and the implicit theory common among the four participants.

Assertion 1: Time constraints and lack of teaching experience made inquiry teaching difficult to implement for the first year teachers in this study.

Inquiry is central to science. "Collaborative inquiry" was emphasized in the TEEMS program. In discussing teaching methods with all four participants we noticed an unclear aspect of our dialogue when the term "inquiry" was being used. Tina connected the term with critical thinking. Cheryl related it to situations when her students had an opportunity to "figure things out" on their own. Laura defined inquiry as teaching situations in which "students build their own knowledge . . . build upon what they have and let them continue to build it themselves." Ed and I talked about it without him ever defining it.

Although Tina, Cheryl, Laura, and Ed frequently utilized hands-on activities in their science teaching, their characteristic teaching format placed information giving ahead of student

activity. This is antithetical to inquiry teaching and the constructivist teaching model promoted in TEEMS. Tina used the term "inquiry" to describe the aspects of TEEMS that had transferred to her teaching practice. Although the lab activities Tina described involved hypothesizing and guided questions, it was nonetheless a teacher driven procedure.

The reference to "inquiry teaching" in this assertion refers to science teaching methods in which students are involved in activities that will allow them to "study the natural world and propose explanations based on evidence derived from their work" (NRC, 1996, p. 23). "Inquiry teaching" by this definition places activity ahead of explanation. Thus, if students are not first conducting scientific work from which they generate evidence and then formulating explanations from their work, they are not doing "inquiry." Inquiry teaching by that definition is a tall order.

Cheryl, Laura and Ed each expressed the desire and intention to incorporate more inquiry teaching in their practice, but simply said that they did not have many ideas for converting their science content knowledge into inquiry-based learning activities. Laura spoke to the possibility that as she continues to gain teaching experience, she may develop more inquiry teaching ideas.

> If I was more comfortable and knew more inquiry type things to do . . . I just don't know a lot of things to do and I can't think of something all the time, some kind of inquiry activity to do. Probably if I had more practice at it I think that that would work just as well as trying to focus on content so much.

Ed explicitly spoke to the frustration of believing in inquiry teaching but not having the time to implement it.

> I think the frustration is that I'm a beginning teacher and I love this inquiry idea, but I don't have enough ideas to do the inquiry. It tugs at you two ways, you want to do the inquiry, but you don't have the ideas.

<u>Assertion 2: Classroom management strategies evolved through interaction with students: A commitment to teaching and supportive relationships at the school helped the first year teachers negotiate a satisfying role.</u>

Each of these first-year teachers had classroom management issues that were more pronounced during the first semester. When I spoke to these teachers, it was the early spring of their first year. They were each teaching their second group of students and all but Ed were teaching the same course preparation for the second time. Thus, when I met with them they were at a point in their first year to feel somewhat accomplished and confident. They all expressed feelings of satisfaction and some measure of effectiveness in their teaching role. They would not have gotten to that point had they not learned better management strategies. For Tina it centered on her special needs students. Cheryl modified her rules and procedures for a bit stricter management style. She did not have to give up much of her "laid-back" demeanor to feel more effective in classroom management. Laura responded to students with a life-experience different than hers. To make it work in the classroom she had to teach some students how to interact in a positive manner. Ed perhaps had the toughest transition of all. He had planned for teaching serious astronomy students, but instead he got large numbers of students looking for the easy way out. As Ed put it, he stood his ground, modified his expectations slightly, and taught an activity-based course of a rigor level acceptable to him, given the circumstances.

Each teacher learned classroom management through their daily work with the students. Ed expressed the belief that the TEEMS program could have prepared him better for classroom management.

> One of the needs would have been classroom management. They always said that was going to be covered in your other classes. When you take Sociology or Child Psychology those will be covered, but they didn't! They never addressed that. I did not have a lot of issues with behavior, but I did have some issues that I wish I could have been prepared much better for.

In contrast, Laura felt like she had prepared herself, while in the TEEMS program, to deal with classroom management.

> (TEEMS) just showed me how to use the routines. Classroom management was probably the biggest thing I focused on, because I knew that was probably where I was going to have the most problems.

Both Ed and Laura said they greatly benefited from the county mentor who observed and spoke with them weekly during their first year. Cheryl and Tina agreed that there was only so much a pre-service program could teach regarding classroom management. They felt that experience was the best teacher.

Each teacher described a process of learning classroom management through experience. All four teachers described his or her school as a supportive environment. Furthermore, there is personal background information revealed by each participant that seems to present them each as having a high level of commitment to teaching. We think all three factors, (teaching experience, supportive colleagues, commitment to teaching) contributed to the development of classroom management strategies for these teachers.

<u>Assertion 3: Common elements of a daily instructional strategy emerged as teachers adapted what they learned in the preservice program.</u>

The common lesson format of agenda, structured notes, activity, and review is interesting in that each participant mentioned those four elements in that particular order. The professors in the preservice program never taught that as a lesson plan format. The school system did not require that format either. So what accounts for the common instructional format?

I think these similarities in lesson format reveal aspects of implicit theory, or what teachers find to work in their school context. The three school contexts in this study were all operating on the 4 X 4 block schedule. The 90-minute time frame for each class period promotes dividing the lesson into segments.

TEEMS emphasized activity-based learning, so we were not surprised to see the emphasis on activities in these teachers implicit theories. That each of the participants frequently

taught through collaborative and hands-on activities is a congruence between the TEEMS program and at least four of its graduates. Also, the emphasis on structured notes, in a discussion format, and for only a 20-30 minute portion of the time block seemed to be an adaptation or the most suitable fit for their teaching practice in the school environment in which they worked.

The placement of structured notes ahead of group activity is not a practice that would be endorsed by a teacher-education program promoting lesson design based on constructivist theory. This seems to be these teachers' adaptation to their inability to teach any other way. As they have expressed, it is difficult to come up with ideas for inquiry teaching, and there are only so many hours in a first-year teachers' day.

Assertion 4: TEEMS influenced these first year teachers to consistently utilize grouping strategies to foster individual engagement and promote group collaboration.

The greatest similarity between what occurred in the TEEMS program and what occurred in the classrooms of these four first-year teachers was group collaboration. Small group interaction for the purpose of meeting instructional objectives was a daily part of the TEEMS program. All four participants utilized grouping strategies in their classes. Cheryl, Tina, and Laura used collaborative groups frequently. When Ed launched into a ranking of what elements from TEEMS had helped him establish his classroom climate, he listed lesson planning, demonstrations, and technology use, ahead of grouping strategies. Nevertheless, in his frequent groupings of paired students in lab, he adopted strategies that promoted interaction and collaboration:

> I walk around during labs. My policy is, in order for me to come answer your questions, whether on worksheets, or on labs, is that either the whole group raised their hand or I don't go over there. They have to explain the problem to each other and then I go over there and I ask them a question about the problem.

Each of the participants expressed that group work was rarely (if ever) used by their high school teachers. Comments such as the quote below from Cheryl lead me to attribute to the TEEMS program the emphasis on peer collaboration expressed by these four teachers.

> The TEEMS program has been a big influence with the whole idea of group work, because that was something I never really experienced (before TEEMS). There are so many different types of group work that I do, from having them do mini-groups on teaching presentations, to just working with the person next to you in brainstorming ideas, to writing something on a poster and sticking it on the wall and telling your description of it.

Assertion 5: A congruence existed between the first-year teachers' implicit theories and the social/experiential design of TEEMS. This congruence is evidence that the TEEMS program has narrowed the gap between educational theory and practice.

All four teachers described collaborative grouping and hands-on activities to be important parts of their explanation of "what worked" in their first year teaching practice. These elements of their teaching work are in line with the social constructivism and experiential education that characterized the TEEMS program.

At the end of their first year of teaching, the participants of the study had a favorable view of the TEEMS program. These four first year teachers never dismissed their preservice program as irrelevant or impractical. In its social and experiential design, the TEEMS program has narrowed the theory/practice gap, at least for these four teachers. Wideen et al. (1998) asserted that teachers who emerge from preservice programs in which theory is integrated with practice are more likely to negotiate satisfying roles in the initial induction phase. These results are in agreement with that finding.

Korthagen and Kessels (1999) asserted that "realistic teacher education" which proceeds from practice to theory precludes the theory/practice gap. They held that when teacher education programs involve students in practical experiences on which to build discussion about

educational theory, the long discussed theory/practice gap is not created in the first place. As we think about the substance of the TEEMS program in relation to the implicit theories expressed by the participants, we see a scenario not unlike that described by Korthagen and Kessels (1999). The first-year teachers involved in this study did not speak of the preservice program as irrelevant to their teaching work, but rather seemed to be adapting the most social and experiential elements of constructivist pedagogy.

The TEEMS program, more than anything else, was based on social constructivism. The participants spent a year with a cohort in an environment designed to foster group interaction and inquiry into teaching. Sessions at the university always involved small group interaction for specified academic purposes. Thus, to see these teachers emphasize collaborative grouping and frequent hands-on activities in their science teaching indicates a close congruence between the explicit theory of TEEMS and the implicit theory generated in first-year teaching.

The TEEMS program was inquiry-based, yet inquiry teaching was rare in the classrooms of these four TEEMS graduates. This would seem to be a gap between educational theory and practice. Considering the differences in inquiry into teaching and scientific inquiry clarifies the above issue and also yields the following implication.

Implication: Science teacher-education should include both inquiry into teaching and scientific inquiry

One element of pedagogy not strongly represented in these first-year teachers' practice was scientific inquiry. The TEEMS program was based on inquiry into science teaching, but did not contain many explicit experiences in scientific inquiry. Project Ozone served as one scenario in which the TEEMS students "proposed explanations based on evidence" (NRC, 1996, p. 23). The TEEMS program, and any science education program that is founded on constructivist

principles, should accept the challenge of engaging preservice teachers in frequent opportunities to utilize scientific inquiry in the context of science concepts which will be the subject of ones teaching practice.

All four participants placed "structured notes" ahead of "group activities" in their typical lesson plan. These first year teachers found it difficult to devise inquiry experiences in the context of the science content that they taught. Further compounding the problem was the fact that many of the science content courses taken by these students while in TEEMS were traditionally taught lecture-based courses. These do not promote scientific inquiry.

As it has been traditionally directed, the academic science major rarely engages the prospective science teacher in considering the content in ways in which they must know it for teaching. Professors in the College of Arts and Sciences convey vast amounts of specialized knowledge through their typically lecture-driven pedagogy. Even if lecture is accompanied by opportunity for dialogue, the science learned by the aspiring teachers is not being learned for the intention of teaching. As Shulman (1986) pointed out, it is pedagogical content knowledge that separates the one who merely knows the subject, from the one who knows it for teaching. I consider "pedagogical knowing" to be a better conception of this knowing for the purpose of teaching (Stengel, 1997). Pedagogical knowing describes a dynamic process in which effective teachers reconstruct their knowledge of the subject matter for the purpose of teaching. Effective teachers learn from experience, not only classroom management techniques, but also an always-widening repertoire of ways to convey subject matter.

Stengel (1997) challenged us to "problematize the traditional academic major as a sufficient condition for teachers' subject matter knowledge" (p. 50). A problem does in fact exist

on any university campus where the science education program promotes progressive pedagogy and the science professors teach in predominantly traditional ways. This is a common scenario.

To design and implement activities in which student exploration precedes the explanation phase requires a fluent and flexible knowledge of subject matter. Although this pedagogical knowledge develops through years of teaching practice, preservice teacher education experiences can help the novice teacher to begin to see both the challenges and rewards of scientific inquiry in the classroom. Science teacher-education students should be provided some experiences in scientific inquiry. They should also collaborate to develop lesson plans that will engage secondary students in scientific inquiry. Such experiences might hasten the teachers' growth in pedagogical knowing.

Implication: Teacher education that goes from practice to theory mitigates the gap

> There's very little practical application for much of what is taught at the university. Instead of all that theory, I wish they would provide students with more practical applications. (Kagan, 1993, p. 109)

The above quote is but one documented example of a prevalent view among secondary teachers. The theory/practice gap in education is bounded by a difference in perspective. On one side of the bridge secondary science teachers are busily attending to the daily agenda of teaching their students. On the other side of the bridge, university professors are conducting scholarly research while they prepare new teachers who will soon join the teaching ranks. One group generates educational theory. The other group, whether they realize it or not, daily practices a theory of their own. Many have noted the theory/practice gap over which we stand. It has been there for decades. The bridge that we stand on is the hopeful part of this metaphor. It is this bridge to which we must give our attention.

Prevalence of Traditional Pedagogy and the Theory/Practice Gap

Regarding the specific domain of science education, progressive pedagogies of "inquiry teaching" and "experiential education" have been increasingly common in teacher education programs since the late 1950s. Nevertheless, traditional teacher-centered classrooms that restrict students' involvement in the learning process have been far more prevalent than student-centered, constructivist classrooms. In the Educational Equality Project, cited by Coble & Koballa (1996), two myths were given as contributors to the poor condition of science achievement by students in the United States as compared to other industrialized nations.

> The first is the widespread belief that the ability to learn science is possessed by only a select few. The second myth is that studying science primarily involves memorizing facts found in textbooks and that performing experiments is simply an exercise in verifying known phenomena. (p. 459)

Such myth-guided thinking, in my view, closely parallels a conservative, traditional view of teaching. Science reform initiatives such as the American Association for the Advancement of Science's Project 2061 and the National Science Teachers Association's Scope, Sequence and Coordination Project clearly promote a progressive pedagogy based on constructivist theory.

In the most recent edition of the Handbook of Research on Teacher Education, Coble and Koballa (1996) assert that reform in science education hinges on a new conception of teaching.

> Consistent with the new vision, the teacher must assist students to construct new knowledge. The teacher can no longer be the giver of factual information; rather the teacher must be a facilitator and role model who gently guides students through the adventure of learning, encouraging them with questions and feedback and sharing their curiosities and excitement. The teacher must operate as part of a learning community where questions about the natural world or human problems spur investigation and where the ideas generated from investigation are communicated and acted upon. (p. 462)

The vision of science education described by Coble and Koballa (1996) demands that changes occur in the culture of both science education and science teacher education. Teachers must be the focus of educational reform efforts. This is so because teachers are directly responsible for implementing the changes associated with this new vision of science education in the classrooms. However, what is known about the attitudes, beliefs, and actions of science teachers suggests that they are not adequately prepared to enact the changes that accompany this new vision of science education. For this reason, science teacher education is of critical importance in the broader reform effort (Bruner, 1992).

From the perspective of many secondary science teachers, the theory/practice gap is expressed in terms of disdain for “all that theory” they find of little use in their work as teachers. As teacher educators, we should be interested in narrowing the theory/practice gap, or perhaps even preventing it from being created in the first place.

Kagan’s (1993) assertion that classroom teachers describe their teaching in terms of human relationships and interaction supports our finding that the TEEMS program narrowed the theory/practice gap. Each first-year teacher in this study held an experiential view of pedagogy. Just as the TEEMS program emphasized group collaboration, so did the teaching practice of these participants. That the participants’ first year teaching did not show an abundance of “inquiry teaching” presents an area of future research centering on the time and contextual constraints which impact the pedagogical intention.

Since the theory/practice “gap” is a metaphorical construct, it seems to be a somewhat intangible claim to assert that, for these four participants, the gap was narrowed by a particular type of teacher education program. We make this claim because 1) all four participants found their first year of teaching to be both effective and fulfilling, 2) the participants never discounted

the value of the teacher education program in any way, and 3) most importantly, the most prominent feature of the preservice program, social constructivism, emerged as a strong pedagogical pattern. The results of this study are very much in line with the assertions of Wideen et al. (1998) that program designs that build upon the beliefs of the beginning teacher are a more productive approach than transmitting theory to be applied by novice teachers in practice. Furthermore, these results serve as a case in agreement with Korthagen and Kessels' (1999) assertion that a preservice process that goes from practice to theory narrows the gap by providing concrete situations that serve as reference points throughout the induction phase.

It seems that both the pedagogical thrust of the preservice program and the supportive contexts in which the first year teachers worked, assisted these first-year teachers in negotiating a satisfying teaching role. The unique elements of each participant's personal biography point to a strong commitment to the teaching profession. Each of these factors contributed significantly in helping these teachers to overcome challenges posed by their students and the transition shock of the first year of teaching. It was in the relationships with students, those human interactions, that we see the empowering influence of a teacher-education program, a supportive school context, and a personal commitment to teaching bear the fruit of a rewarding teaching experience.

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RECONCEPTUALIZING A GENERAL CHEMISTRY CURRICULUM USING A STANDARDS-BASED APPROACH TO INSTRUCTION

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Over the past decade, various commissions and government panels have reported a lack of science literacy among young people, accompanied by negative attitudes toward science (National Governor's Association, 1991; Commission on the Skills of the American Workforce, 1990; Carnegie Forum on Education and the Economy, 1986; National Commission on Excellence in Education, 1983). To them, science is perceived as boring, irrelevant, and difficult to learn. University level general chemistry courses are not immune to this national problem, and both low student performance and interest have been observed and documented in these introductory courses (Barrow, 1994; NSF, 1987). Not surprisingly, groups concerned about the role of science and technology have issued a clarion call for science education reform (National Science Teachers Association, 1992; American Association for the Advancement of Science, 1993, 1989; NRC, 1996; NSF, 1996). One way for institutions of higher education to participate in the reform effort is to offer science courses that use a Standards-based (NRC, 1996) approach to instruction. In the area of chemistry, the National Science Foundation developed a program designed to improve beginning chemistry courses and the American Chemical Society formed a task force to look into improving general chemistry (Abraham, Cracolica, Graves, Adhmaash, Kihega, Gil & Varghese 1997) to assist institutions of higher education in this effort.

Traditional chemistry teaching in high enrollment courses relies heavily on lecture, in which the presentation of chemical concepts and equations are scribed, memorized, and reproduced by students (Zoeller, 1999). In a formal lecture-oriented teaching style, students perceive the learning of chemistry as a passive method for learning. As such, they do not try to

understand the underlying chemical concepts and relationships (Zoeller, 1999). The change from a curriculum that is focused on a rigid body of facts revealed by the instructor and text to one on that is student-centered will increase students' understanding and performance and will also result in students who have a more favorable attitude towards chemistry. In other words, a Standards-based approach to instruction is needed in these introductory general chemistry courses.

The General Chemistry Program at UNC Charlotte

Approximately 1300 undergraduate students enroll in the general chemistry program at The University of North Carolina at Charlotte each year. The general chemistry program is comprised of three different two-semester general chemistry tracks: CHEM 1251/1252 for all science and engineering majors, CHEM 1111/1112 for non-science majors, and CHEM 1203/1204 for nursing majors. The CHEM 1251 course has the highest enrollment, and is approximately 850 students per year including secondary education students seeking professional licensure in biology, chemistry, earth science, physics, and comprehensive science. Students often begin this course knowing that the D/F ratio is alarmingly high (approximately 42%). In addition, students often believe that CHEM 1251 is one of the "weed-out" courses for science majors. As a result, students frequently begin CHEM 1251 with a loaded perception--the course is very difficult and I will not do well!

The Chemistry Department has attempted to increase student performance in CHEM 1251 over the past 6 years by implementing a number of changes including, tracking students into different sections based on their ability, employing various instructional strategies such as demonstrations and work sheets, and creating open-ended lab experiments to promote critical thinking skills. All of these changes were made with the hope of increasing student interest,

involvement, and achievement. While a great amount of effort had been placed on improving the presentation of material, the primary method of instruction continued to be passive didactic lectures. In addition, lecture and laboratory were disjointed with respect to the logistical presentation of chemical content and concepts. The aforementioned changes resulted in little or no improvement in student performance. However, analysis of course and instructor evaluations showed a significant improvement in student attitude toward chemistry in sections when interactive learning experiences were incorporated into the lecture. The observation that student interest increased when interactive learning experiences were used lead us to hypothesize that student interest, motivation, and performance all would increase if CHEM 1251 was reconceptualized and grounded in the tenets of the National Science Education Standards (NRC, 1996). Our effort to implement a Standards-based approach into CHEM 1251 has been termed Operation CHEM 1251.

Project CHEM 1251

Project Goals and Objectives

It has been well documented that lecture presentations are a passive style of learning and offer little to involve students in the learning process (Ausubel, 1963; NSF, 1989; VonGlassersfeld, 1995). The change from a curriculum that is focused on the instructor to one that is student centered will not only increase student performance but will also result in students who have more favorable attitudes toward chemistry. As such, The major goal of Operation CHEM 1251 was to reconceptualize CHEM 1251 by developing and implementing a curriculum and an approach to instruction that is grounded in the tenets of the NSES (1996). A Standards-based approach to instruction includes, but is not limited to, the incorporation of inquiry, reflection, critical discourse and collaborative learning experiences. In such an environment,

chemistry instructors become facilitators, helping students in the construction of their knowledge instead of dispensers of facts and concepts. As such, the traditional lecture hall becomes more student-centered.

A key objective of the project was to develop a learning environment that allowed the students to discover the content, concepts, and relationships of chemistry through active learning experiences. Active learning experiences involve the processes of inquiry, collaboration, reflection, and critical discourse. Each of these has been shown to independently promote student understanding (Bunce, 1997; Staver, 1998). In addition, the use of inquiry has been shown to enhance some students' interest in science as well as their motivation to continue studying science (Damnjanovic, 1999). For the purposes of this project, a Standards-based approach to instruction includes the use of: 1) open-ended inquiry, 2) collaborative learning, 3) active participation during lecture sessions, 4) incorporation of relevant material, and 5) integration of the laboratory with the lecture material.

Reconceptualizing CHEM 1251

Four to eight sections of CHEM 1251 were offered each semester for the past three years. One section each semester, taught by Eugene P. Wagner, was the experimental section while the other course sections comprised the control group. In the fall of 1997, the first semester of Operation CHEM 1251, the experimental 1251 section was taught in a traditional lecture format similar to the seven other concurrent 1251 course sections. During the spring 1998, fall 1998, and spring 1999 semesters, incremental changes in the experimental section were made and base-line data were collected.

During both the spring 1998 and fall 1998 semesters, simple collaborative learning exercises were introduced into the lecture. These exercises were designed to increase student

involvement during class. In the spring 1999 semester, a constructivist approach to teaching and learning was introduced in the experimental section. During this semester, chemical concepts and relationships were only presented in class to the point at which students would have the requisite background needed to start working collaboratively on a problem. Once this was accomplished, students worked collaboratively to find a solution for the problem. The students shared their evolving thoughts, developing insights, and understanding of chemical concepts and principles prior to any formal presentation in class.

Starting with the spring 1998 semester, interactive lecture notes were made available to the students through the University bookstore. The purpose for providing lecture notes was to decrease the amount of time students spent scribing notes during class and increase the interaction time among the students and instructor. The notes were incomplete and allowed the students to follow along during class. Many of the interactive exercises used in the class were included in the notes, thus decreasing the time students would normally spend copying problems from the board. The interactive lecture notes and the collaborative exercises were the only two significant changes made in the experimental section during the spring 1998 and fall 1998 semesters. Over this period, instructors in the control group continued to present primarily in a traditional lecture style.

Full implementation of the reconceptualized CHEM 1251 curriculum was achieved during the spring 1999 semester. The focus of the project during this semester was to collect baseline data and assess the effect of incorporating a Standards-based instructional strategy. Specifically, this involved (1) reconfiguring the weekly class schedule for the experimental section so as to meet for two three-hour blocks of time each week, (2) integrating laboratory and lecture, and (3) structuring learning experiences in a learning cycle format (Renner & Marck,

1988). The experimental section met once per week for a three-hour lab that was also taught by the lecture instructor.

Methods of Analysis

Relative comparison of student academic ability, performance, and background knowledge was conducted through both SAT scores and student pre-semester assessment (SPSA) scores. The SPSA is a multiple-choice exam consisting of 10 math questions and 10 chemistry questions administered during the first week of the semester. The math questions focused primarily on algebra and unit conversion. The chemistry questions were designed in such a manner that students with no previous formal chemistry knowledge would still be able to analyze the question and determine the correct answer. The purpose of the SPSA was to compare students between the experimental and control groups on requisite math ability and prior chemistry knowledge (Wagner, DiBiase, 1998). Although enrollment in CHEM 1251 does not require any previous formal chemistry experience, approximately 90 percent of the students enrolled in 1251 have had at least one semester of chemistry. In addition, a demographic survey designed to compare relative differences between the control and experimental groups was administered at the beginning of the semester. The seven demographic categories included items such as age, highest level of mathematics, and hours of work at a job per week. In addition, six Likert scale questions addressed the reasons students enrolled in their respective course sections. The purpose for including this survey was to confirm that course selection was not due to student's knowledge that the experimental section was unique.

Performance in the 1251 course was monitored through four common exams and the American Chemical Society (ACS) National Standardized End-of-Semester Exam. Students in all concurrent 1251 sections were administered the same four multiple-choice exams and the

ACS Exam. The common exam plan has been used in the 1251 program for the past four years. The exams are created thorough a collaborative effort among all faculty teaching 1251 each semester. In addition, end-of-semester course evaluations were used to compare the responses of students in the experimental and control groups. The end-of-semester course evaluation is an 18 question Likert scale survey administered during the last week of the course. Student t-tests were used analyze any significant differences between the experimental and control groups in all data collected except for the demographics survey and the end-of-course evaluation. Chi-squared analysis was used for the demographics survey. The scores on the end-of-course evaluation for the experimental section were compared to the average and standard deviation of the control group for all 18 questions on the evaluation.

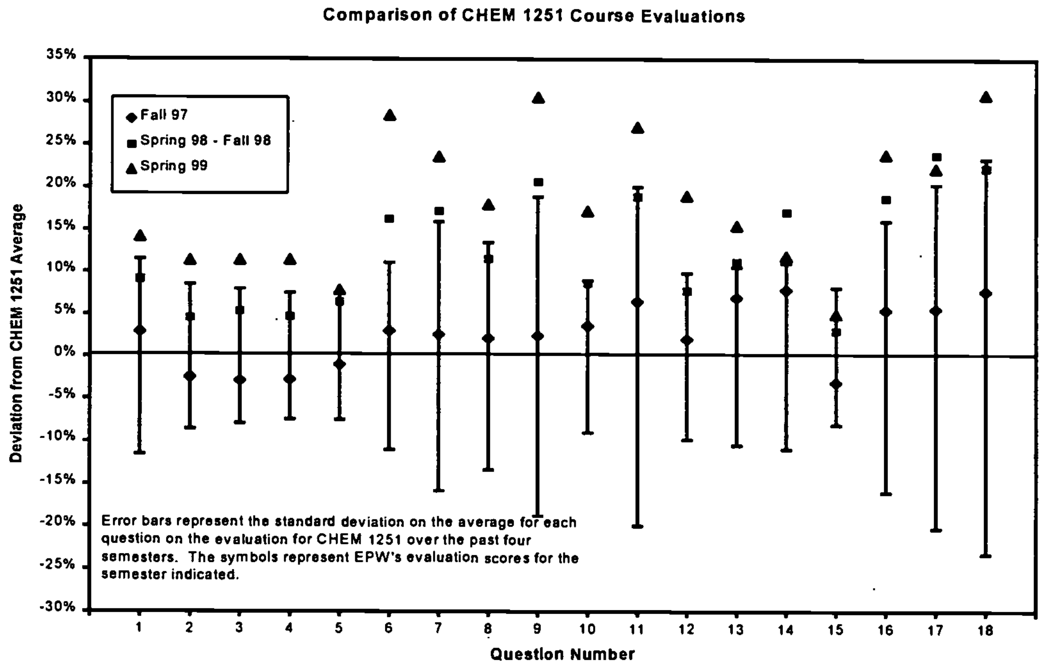
Results and Discussion

Analysis of data from the fall 1997 semester showed no significant difference in the SAT and SPSA scores between the experimental and control sections. In addition, no significant difference was found in end-of-course evaluations (Figure 1). All daytime course sections showed no statistically significant difference for the exam averages (Figure 2).

Analysis of data from both the spring 1998 and fall 1998 semesters again showed no statistically significant difference in student background or performance among daytime course sections. However, improvement in course evaluations for the experimental section over the fall 1997 semester was recorded for all 18 questions on the survey. Furthermore, significant improvement over the average for all 1251 course sections in five of the eighteen questions was observed (Figure 1). The data suggests that the collaborative learning experiences implemented during these semesters were correlated to the increase in student satisfaction.

Figure 1
Comparison of End-of-Semester Evaluations (Fall '97 – Spring '99) in Chemistry 1251.

The average for each question is set at zero and the error bars represent the standard deviation on the average of each question for all 1251 instructors over the two-year period. The symbols indicated on the graph are scores for the experimental section.

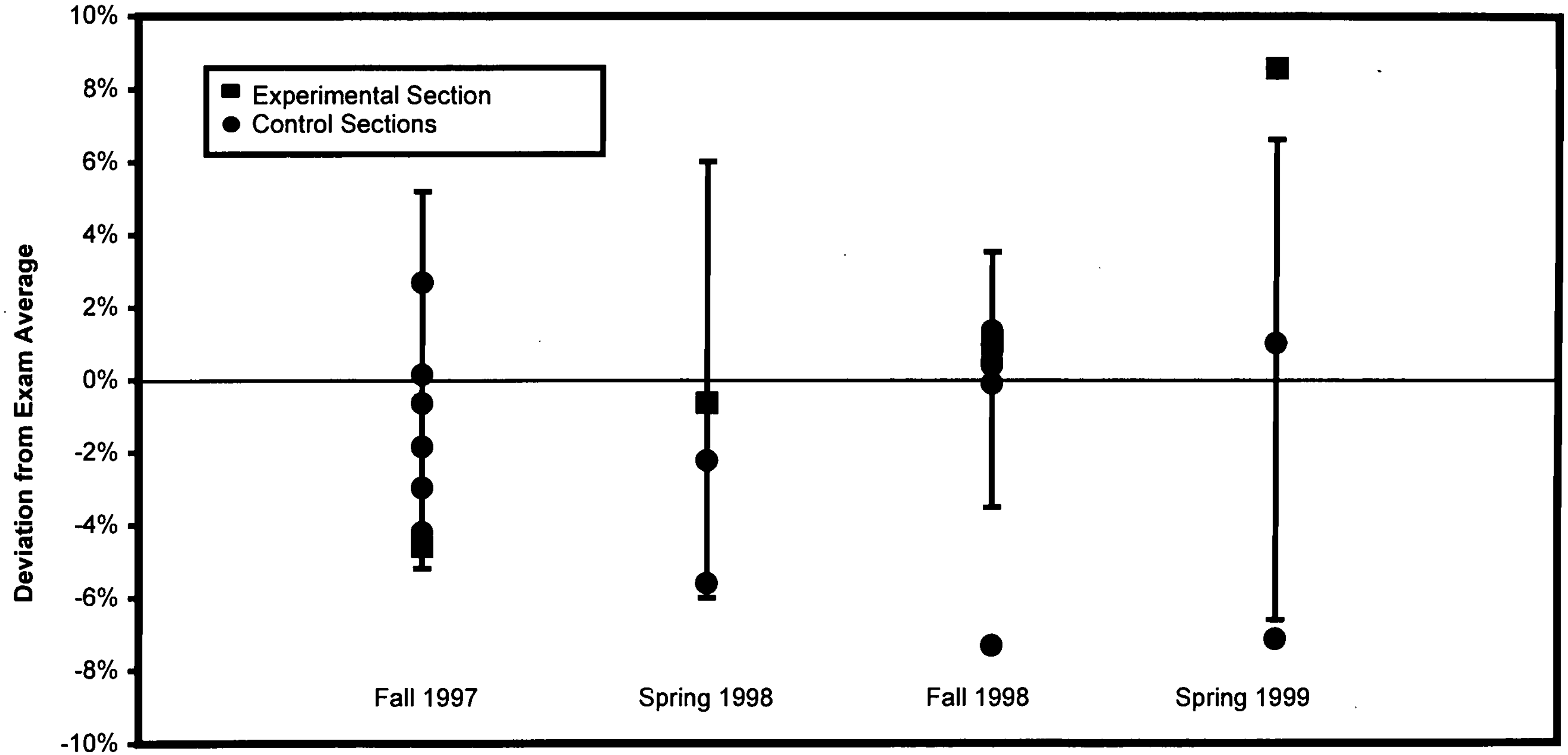


1 My instructor is actively helpful when students have problems.
2 Mutual respect is a concept practiced in this course.
3 I feel free to ask questions in class.
4 My instructor deals fairly and impartially with me
5 When I have a question or a comment, I know it will be respected.
6 My instructor Recognizes and rewards success in this course.
7 My instructor stimulates interest in the course.
8 My instructor makes good use of examples and illustrations.
9 My instructor has an effective style of presentation
10 This course has effectively challenged me to think.
11 My instructor holds the attention of the class.
12 The stated goals of this course are consistently pursued.
13 Exams stress important points of the lecture/text
14 Exams are reasonable in length and difficulty.
15 I am generally pleased with the text(s) required for this course.
16 My interest increased as the course progressed.
17 Overall, this course is among the best I have ever taken.
18 Overall, this instructor is among the best I have known.

Figure 2

Comparison of Class Section Exam Averages in Chemistry 1251.

The exam average is set at zero and the error bars indicate the standard deviation in exam averages for each semester.



Analysis of the data from the SAT, SPSA, demographic survey, and reason for enrolling in specific course section collected in the spring 1999 semester showed no statistically significant difference between the experimental and control groups (Table 1). The data indicates that there was a homogeneous population throughout all four of the 1251 course sections at the beginning of the spring 1999 semester. Data analysis on the instruments used to measure the effect of the reconceptualized curriculum showed a significant increase in both student performance and satisfaction. The experimental group scored a significant 10.7 percent higher on the four common exams and 16.9 percent higher on the ACS End-of-Semester Final Exam (Table 2). The averages for the ACS exam placed the experimental section in the 68^{th} percentile of the nation and the control group in the 42^{nd} percentile of the nation. This is the first time since data collection on exam averages began over five years ago that any daytime 1251 course section scored significantly higher than the other concurrent sections.

Student retention in the experimental section was also greater. Eighty one percent of the students in the experimental section completed all four common exams and the final exam while 73% of the students in the other three course sections completed all exams. The D/F ratio in the experimental section was 25.8 percent compared to 44.5 percent in the control group. The total number of withdrawals from 1251 for the spring 1999 semester was 34, all from sections in the control group.

Table 1

Comparison of Background Variables Between the Experimental and Control Groups for the Spring 1999 Semester.

The fourth column shows the p value obtained through the statistical test show at the top of each category. In all cases, the alpha (α) value was set at 0.05. The variable n represents the number of responses. In all cases, except for the PGI, the null hypothesis was true, indicating no significant difference between the experimental and control groups on the background variable.

Variable	Experimental Average	Control Average	Significant?

ACADEMIC PERFORMANCE			student *t*-test
SAT Total	990 (*n*=23)	1017 (*n*=187)	No, *p* value = 0.21
SAT Math	513 (*n*=23)	522 (*n*=187)	No, *p* value = 0.31
SAT Verbal	487 (*n*=23)	494 (*n*=187)	No, *p* value = 0.22
SPSA (%)	65.1 (*n*=32)	63.9 (*n*=244)	No, *p* value = 0.35
DEMOGRAPHICS (categorical scale, five possible selections for each question)	**(*n*=23)**	**(*n*=187)**	**chi-squared test**
Previous number of semesters of chemistry			No, p value = 0.41
Age			No, *p* value = 0.11
Involvement in University activity			No, *p* value = 0.26
Hours of work at job per week			No, *p* value = 0.95
Highest level of math			No, *p* value = 0.35
High school town size			No, *p* value = 0.20
Year in college			No, *p* value = 0.69
COURSE SECTION SELECTION	**(*n*=18)**	**(*n*=187)**	**student *t*-test**
Reasons for enrolling in specific course section, six Likert scale questions (range 1-5)	3.6	3.7	No, *p* value = 0.16

Table 2

Exam Averages for the Four Common Exams and the ACS Final Exam in the Spring 1999 Semester.

Student *t*-test were used to compare the two groups. The alpha (α) value was set at 0.05, and the variable *n* represents the number of student scores obtained for each group.

Variable	Experimental Average	Control Average	% difference ((E-C)/C)*100	Significant?
Exam Average (%)	68.6 (*n*=26)	61.4 (*n*=182)	10.7	Yes, *p* value = 0.026
ACS Final Exam Average (number correct out of 70 questions)	45.0 (*n*=25)	37.4 (*n*=191)	16.9	Yes, *p* value = 0.0024

Continued Work

Data analysis from Operation CHEM 1251 is ongoing. The results of this phase of data analysis demonstrate that no difference in background and ability existed between students in the experimental or control sections at the beginning of the spring 1999 semester. However,

students in the experimental section showed a significant increase in student performance and attitude toward chemistry (and the 1251 course). Several potential factors may be responsible for the noted increase in performance and attitude. The factors include the following: students in the experimental section traveled as a cohort between laboratory and lecture portions of the class, motivational factors not measured, and possibly just the random event that many "good" students enrolled in the same section. However, other subtle changes occurred without any conscious effort on the part of the instructor. For example, a better rapport and relationship developed among the students and instructor as a result of increased interaction and dialogue in lecture and having the same instructor for both laboratory and lecture portions of the class. In other words, as Palmer (1993) suggests, the instructor was able to *know* each of the students in the experimental section. Working in such an environment lowered the anxiety level of the students, which normally runs at a high level in this course. The effect of social interaction on performance can be an elusive topic, but it certainly appeared to have an overall positive effect on the experimental section.

Reconfiguring the weekly class schedule and integrating laboratory and lecture learning experiences allowed for a natural crossover of topics. The integration between laboratory and lecture continued to grow and reinforce each other as the semester progressed. While there may still be other small factors contributing to increased performance, there does not appear to be any one overwhelming baseline factor affecting this difference in performance. There is a very good indication that the Standards-based approach to instruction significantly increased both student performance and affect.

In subsequent semesters, the laboratory associated with the experimental class section was configured into two 80-minute meetings per week that immediately followed the lecture

every Tuesday and Thursday. The purpose of this change was to promote the mixing of lecture and lab concepts presented on a daily basis. The lecture incorporated pre-lab and post-lab discussions, and the lab exemplified the concepts discussed in class. The lab experiments were also redesigned to be completed in an 80-minute period. In the spring of 2000, the exams incorporated open-response questions. Analysis of the students' responses to these questions will provide valuable insights into the students thought processes. Data continues to be gathered and analyzed for these semesters in much of the same manner as the spring 1999 semester. In addition, semi-structured interviews were conducted with both laboratory instructors and students randomly selected from both the experimental and control sections. It is expected that a comprehensive analysis of all data collected during the fall 1999 and spring 2000 semesters will solidify that this Standards-based approach to curriculum and instruction significantly improves student performance and affect in general chemistry.

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DOCUMENTING STRATEGIES FOR TWO LOCAL SYSTEMIC CHANGE PROJECTS

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Science teaching, science learning, and science teacher education research have enjoyed increased attention and funding in recent years since the publication of the *National Research Council's National Science Education Standards* (NRC, 1996), the *National Board for Professional Teaching Standards* (NBPTS, 1994), and the *Report of the National Commission on Teaching and America's Future* (Darling-Hammond, 1996). These reform documents reaffirm the importance of teachers, teaching, and hands-on/minds-on learning as primary influences on students' thinking, achievement, and science literacy. Collectively, the documents provide a vision of what we should teach, how we should teach, what kinds of systems and programs we should teach in, and how we should teach teachers to teach.

This paper describes efforts to effect major reform of the elementary school science curricula in two different projects and the attempts to document changes resulting from these efforts. The two projects are the "Science-Parents, Activities and Literature" (Science PALs) project (1994-1998, NSF Grant ESI 9353690) and the recent "Science Cooperatives: Effecting Systemic Change in Rural Missouri, Iowa and Minnesota" (Science Co-op) project (2000-2005, NSF Grant ESI 9911857). These two projects represent a natural progression of research and development in which an innovation is developed and tested in a single, well-defined condition and then implemented in a much larger and less well-defined situation.

Background

An analysis of the reform documents for language arts, mathematics, science, social studies, and technology revealed a common focus on "all" students, common learning outcomes of literacy and critical thinking, and common instructional intentions regarding constructivism and authentic assessment (Ford, Yore, & Anthony, 1997). Science literacy, like the other contemporary literacies, involves critical thinking, cognitive abilities and habits-of-mind to construct understanding in the specific disciplines, the big ideas or the unifying concepts of the disciplines, and the communication skills to share these understandings and to persuade others to take informed action.

Unfortunately, little attention has been given to developing a concise, clear definition of constructivism and of the associated classroom practices. The National Standards for Science Education (NSES) envisioned a change in emphasis involving children's attributes, rigidity of curriculum, relevant learning outcomes, active questioning, alternative assessment, locus of control, and collaboration (NRC, 1996). The National Science Teachers Association (1997) encourages teachers to increase their awareness of these emerging standards for teaching, professional development, assessment, content, program, and the full education system. Analysis of the reform documents, the research literature, and the professional journals reveals that there are many faces of constructivism being used and advocated. The face is determined by the worldview, the epistemology and ontology of science, model of learning, locus of control, and roles of discourse. It is essential, therefore, to specify which of these are being discussed and being advocated in any given instance. Clearly, proponents of the current science reform believe it is not enough to specify learning outcomes without emphasizing the quality of the learning experience, the authenticity of the evaluation, and the availability of learning opportunities.

The interactive-constructivist brand of science teaching promoted in the Science PALs and Science Co-op projects is a middle-of-the-road interpretation of constructivism involving the elements of inquiry – engagement, exploration, consolidation, and assessment. Interactive-constructivist teaching recognizes a specific worldview of thinking, the epistemological and ontological nature of science, the locus of mental activity in the learner, the socio-cultural aspects of the classroom, the multiple purposes of language, and the realities of public education and schools (Shymansky, et al, 1997b; Yore & Shymansky, 1997). Interactive-constructivist science teaching assumes that contemporary science is based on a hybrid view of knowing that stresses the importance of interactions with the physical world and the sociocultural context in which interpretations of these experiences reflect the lived experiences and cultural beliefs of the knowers (Prawat & Floden, 1994).

An interactive-constructivist perspective also assumes an epistemological and ontological view of science that stresses evaluation of knowledge. This evaluation requires that explanations and interpretations are judged against the available data and canonical theories using evidence from Nature and scientific warrants to justify claims about reality (Hofer & Pintrich, 1997; Kuhn, 1993). The locus of mental activity and construction of understanding in interactive-constructivism involves both a private and public component – unlike social constructivism, which defines understanding as group consensus building, or radical constructivism, which defines understanding as a uniquely individual decision (Hennessey, 1994; Prawat & Floden, 1994). An interactive-constructivist perspective assumes that discourse reveals the variety of alternative interpretations but that consensus need not be reached. It is evidence from Nature that supports or rejects the interpretations, not consensus (Fosnot, 1996; Prawat & Floden, 1994). The language conventions and traditions of the science community help shape the knowledge

constructed via the discourse. The locus of control for learning in the collaborative interactive-constructive model is shared by the learner and the teacher. The basic assumptions about the role of prior knowledge, the plausibility of alternative ideas, and the resiliency of these ideas are preserved in an interactive-constructivist perspective. But professional wisdom, the accountability of public education, and the priorities of elementary schools must mediate decisions about what to teach and how to teach in the science classroom.

Science PALs

"The Science-Parents, Activities and Literature" (Science PALs) project is an on-going local systemic reform effort in a single school district that was originally funded by the National Science Foundation with supplemental support from the Howard Hughes Medical Institute. The school district had a kit-based science curriculum supported by a science coordinator and a materials distribution center. The kits contained exemplary National Science Foundation (NSF) supported materials from recent curriculum projects and others based on the 1960s NSF-funded projects. The kits were delivered to the district teachers on a rotating basis. While the students enjoyed doing activities, there was a concern among the teachers and district staff that students were not developing meaningful science understandings from the experiences. It was generally acknowledged that the typical elementary school teacher in the district had little understanding of the science concepts explored in the kits, was uncomfortable teaching science, and believed that simply doing activities would enhance students' science knowledge, process and thinking skills.

During the funded period K-6 teachers and Grades 7-12 science teachers participated in summer workshops and school year inservice activities. In addition to the teachers, approximately 3,400 parents participated in special training sessions designed to integrate them

into the K-6 science instruction. Across the four funded years of Science PALs, teachers received an average of 110 hours of inservice education to enhance their pedagogical-content knowledge.

The first year of the Science PALs Project began with 16 elementary school teachers designated as science advocates – one from each elementary school in the district. The science advocates began the project by attending a special, problem-centered summer workshop. That workshop was designed to help participants explore selected NSF-sponsored curriculum units and activities using student ideas as "straw men". The workshop matched science content consultants with small groups of science advocates to explore science concepts in the units selected by grade level groups. Interactive-constructivist teaching strategies focusing on the use of students ideas, literature, and parent partners were modeled and taught in the workshop. Teacher groups customized the science kits with local resources, appropriate children's literature, related misconception literature, authentic case tasks, and supplemental science and interdisciplinary activities.

The summer workshop with the follow-up inservice cycle was expanded in the next three project years involving approximately 40 teachers in the second year, 80 teachers in the third year, and 140 teachers in the fourth year. The inservice cycle focused on authentic problems of curriculum adaptation using activities to challenge teachers' ideas and social interactions and private reflections to get the teachers to rethink their ideas about both the science content of the units and how to teach the units. A similar instructional cycle was then used by the teachers to challenge their students' ideas and to promote conceptual growth among their students. In the last inservice cycles science advocates took over responsibility for the workshop instruction and secondary science teachers served as science consultants. Upon completion of the funded phase, the Science PALs project left a legacy of localized curriculum resources, parental involvement, a

science education leadership team of advocates and secondary science partners, and an ongoing science instruction and professional development program.

Science Co-op

"The Science Cooperatives: Effecting Local Systemic Change in Rural Missouri, Iowa and Minnesota" (Science Co-op) project forms ten cooperatives from 37 school districts in three states. It involves 85 elementary schools and includes more than 1,400 teachers and 20,000 elementary school students. Science Co-op is designed to address the needs of one of the most under-served areas in North America's education system: isolated, small, rural, elementary schools. Science Co-op is based on the farm cooperative movement that allowed small, independent farmers to amass the buying and marketing strength of large farmsteads and to address common problems. Science Co-op organizes the smaller independent school districts into 8 regional units to collaborate on teacher enhancement efforts and to share resources in an attempt to implement the NSES recommendations and NSF-funded elementary science programs (FOSS, Insights, TCS, BSCS). Science Co-op stresses classroom science that involves science inquiry, interactive-constructivist teaching approaches, authentic assessment, and print and electronic resources. It brings together teams of teachers, parents, scientists, and science educators to make science meaningful for children.

Science Co-op uses a combination of summer workshops, regional professional development activities, peer leadership and support (science advocates and science partners), two-way interactive video (ITV), and internet delivery to help elementary teachers construct content-pedagogical knowledge and implement specific science modules that stress reform standards and principles. Since Science Co-op is attempting to model an interactive-constructivist teaching approach based on a modified learning cycle of engage, explore,

consolidate, and assess, it is critical to assess the perceptions and understandings that the participating teachers bring to the project. Some studies have demonstrated that teachers do not value many of the constructivist approaches and the reform principles promoted by the NSES and, in fact, hold preconceptions and beliefs that constitute significant barriers to change (Czerniak, Lumpe & Haney, 1999; Haney, Czerniak & Lumpe, 1996).

Like its Science PALs predecessor, Science Co-op is designed to develop lead elementary teachers (science advocates) and supporting secondary science teachers (science partners) as local leadership teams to promote and facilitate science reform in their local school buildings and school districts and to develop customized science kits which utilize elementary teachers' strengths and local resources. The science advocates and science partners need to understand and value the NSES, become reflective practitioners, and serve as exemplary models of inquiry teaching.

Instruments

Central to the Science PALs and Science Co-op projects is the attempt to document changes in teachers' content-pedagogical knowledge and their classroom practices and in students' achievement, attitudes, and perceptions. Documenting these dimensions in an unstructured and sometimes hostile environment requires creative, sensitive approaches. Before NSF's required evaluations, it was frequently difficult to convince elementary school administrators and teachers that such documentation was valuable. The following documentation strategies were developed in the Science PALs project and are being utilized in the Science Co-op project. Special instruments needed to be developed to reflect the goals and intentions of the projects. The validation of the instruments involved working with data from students, teachers,

and administrators that were not fully oriented with or supportive of the project's goals and intentions. This meant that instrument design was as much an art form as it was a science.

Student's Perceptions of Constructivist Classroom (SPOCC)

The investigators in Science PALs and Science Co-op felt that the deliberate form of interactive-constructivist instruction promoted in the two projects should have been readily apparent to the students involved. The focus, classroom climate, instructional strategies, discourse opportunities, collaboration, and the uses of text promoted in the project were explicit and therefore, should have been detectable. In Science PALs, five-position Likert scale surveys were designed to assess students' levels of agreement: strong agreement (5.0), agreement (4.0), absence of opinion (3.0), agreement (2.0), or strong disagreement (1.0); or judgement of truth: almost always true (5.0), sometimes true (4.0), absence of judgement (3.0), not often true (2.0) or almost never true (1.0) on statements describing their perceptions of science instruction and their affective stance toward science learning (Dunkhase, et al, 1997; Shymansky, et al, 1998a; Yore, et al, 1998a). Validity and reliability of these "Student Perceptions Of Classroom Climate" (SPOCC) surveys were explored using expert analysis, factor analyses, and internal consistency. The construct validity of SPOCC was established by having experts examine the items selected from established item pools or constructed by science educators for the project. Factor analyses were conducted on the 1996 results from the 57-item SPOCC-A for 722 Grade 3 and Grade 4 students and the 72-item SPOCC-B for 999 Grade 5 and Grade 6 students taking the original pool of items. Final versions of the instruments were then constructed using only items that had factor loadings greater than 0.30. The items retained were analyzed again to insure the resulting factors matched the design features of the instrument. The four factors in the perceptual

dimension of SPOCC were identified as the constructivist approach, parental interest, use of literature in science, and relevance of science.

The four factors in the attitudes toward science learning dimension were identified as attitudes toward school science, science self-concept, awareness of the nature of science, and awareness of science careers. Internal consistency of the subscales ranged from 0.49 to 0.85 (Yore, et al, 1998a). The validity of the SPOCC instruments was established further by the patterns of perceptions for different groups of teachers based on experience in the Science PALs project and on supervisor's ratings of the teachers' implementation of the interactive-constructivist approach (Shymansky, et al, 1998b, 1999; Yore, et al, 1998b).

The "2000" versions of the SPOCC developed for the Science Co-op project were modifications of the original SPOCC surveys (Appendix A). The number of planned subscales and the number of items in the subscales were increased to improve validity and reliability. The 60-item SPOCC 2000A survey was administered to 2185 Grade 3 students and the 65-item SPOCC 2000B survey was administered to 2784 Grade 6 students. The results were examined with a series of unconstrained and constrained factor analyses. A 5-factor solution was the best fit and this solution matched the design of the instruments, thereby supporting the structural validity of the two forms. Three factors: Subscale 1--Awareness of the Nature of Science (A: items 1, 4, 5, 6, 8, 9, 10, 11, 13, 17, 24, 27, 28, 30, 58; B: items 12, 14, 20, 25, 26, 27, 30, 51, 58, 59, 61, 31), Subscale 2--Attitudes toward Science, School Science, and Science and Technology Careers (A: items 3, 7, 12, 15, 16, 20, 21, 29; B: items 1, 4, 6, 8, 13, 15, 18, 19, 23, 32), and Subscale 5--Parent, Home and Community Involvement (A: items 18, 22, 32, 46, 48, 50, 54, 56, 59; B: 5, 10, 21, 24, 31, 34, 39, 48, 50, 52, 54, 57, 60) were well-defined components with clear theoretical structure based on the design principles of the instrument. The last two factors were

not as well defined. A second series of factor analyses was therefore done on the restricted set of items from these components (total items less items from the well-defined components). This progressive factor analysis yielded a 2-factor solution with well-defined components: (Subscale 3--Using Children's Ideas, Discourse and Collaboration (A: items 31, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 47, 49, 51, 52, 53, 55, 60; B: items 2, 17, 33, 35, 36, 37, 40, 42, 43, 44, 45, 46, 47, 49, 53, 55, 56, 62, 64) and Subscale 4-- Roles and Value of Text (A: items 2, 14, 19, 23, 25, 26, 57; B: 3, 7, 9, 11, 16, 22, 28, 29, 41). A few items did not load into the desired factor with the traditional 0.30 value, but they were assigned to the theoretical factor since they did not drastically lower the reliability of the subscales (i.e., SPOCC 2000A subscale A1 item #9 and subscale A5 item #18 and SPOCC 2000B subscale B2 item 18, subscale B3 items #17 and #2, and subscale B5 item #31). Reliabilities for SPOCC 2000A subscales ranged from 0.75 to 0.85 and for SPOCC 2000B subscales ranged from 0.82 to 0.89.

Teacher Questionnaire

The current reform in science education calls for rational, reflective, professional teachers who design and deliver science instruction based on content standards, the nature of science, contemporary learning theory, authentic assessment, and inquiry-based curriculum materials. It assumes that science teachers are aware of their instructional decisions and actions and that they are able to justify these decisions and practices utilizing professional standards, appropriate content, and evidence of effective learning. Based on these assumptions, it was decided to develop a Likert-type self-report instrument to document teachers' perceptions of their planning and implementation of interactive-constructivist science instruction, stressing relevant and meaningful instruction, purposeful inquiry, the importance of evidence in science instruction and alternative interpretations in science instruction.

The Science PALs' teachers' perceptions of their planning, teaching, and assessment were documented with a 32-item Likert survey designed to assess strong disagreement (1), disagreement (2), neutrality (3), agreement (4), or strong agreement (5) with specficic ideas related to science curriculum and instruction. Responses from teacher surveys administered in 1996 (N=32), 1997 (N=70) and 1998 (N=140) were factor analyzed to establish structural validity for a questionnaire and to establish the subscales within the survey. The factor analyses of the 1996 responses yielded 8 factors with reasonable loading and conceptual unity-- student-centered features (11 items, alpha = 0.84), social and personal relevance (3 items, alpha = 0.44), misconceptions (3 items, alpha = 0.52), curriculum and planning (7 items, alpha = 0.55), using relevant examples (7 items, alpha = 0.79), using interactive-constructivist approach (5 items, alpha = 0.61), using teaching strategies (5 items, alpha = 0.76), and using language and print resources (7 items, alpha = 0.78). The correlations revealed moderate (0.16 to 0.65) associations between the components within each part of the survey and low (-0.06 to 0.26) associations between the beliefs and externally perceived implementations of the the Science PALs' teaching approach. Factor analyses of the 1997 and 1998 responses revealed that a 3-factor solution was the best fit to the data. The 3 factors were using children's ideas in planning and teaching (11 items, alpha = 0.88), application of science in children's daily lives (10 items, alpha = 0.82), and use of print resources (5 item, alpha = 0.73). Four items did not factor into any component at 0.30 loading.

The 2000 edition of the Teacher Questionnaire was modified to increase the number of items in each subscale and to produce subscales that more closely reflected the interactive-constructivist science teaching approach promoted in the Science Co-op project (Appendix B). The new 48-item questionnaire was administered to 116 elementary and secondary teachers

attending the Science Co-op "summer 2000" workshop. The responses from this group were factor analyzed using a 5-factor solution. The factors were found to have conceptual unity and reasonable reliabilities. Subscale 1: Using student ideas to plan and implement science instruction was composed of 14 items (B: 3, 4, 7, 9, 11, 13, 15, 16, 17, 19, 20, 21, 22, 24) with acceptable loadings and internal consistency of 0.87. Subscale 2: Promoting purposeful science inquiry consisted of 14 items (A: 1, 2, 4, 5, 7, 10, 16, 17, 18, 21, 22, 23, 24; B: 2) with acceptable loadings and an internal consistency of 0.83. Subscale 3: Making science instruction relevant and meaningful to students consists of 9 items (B: 1, 5, 6, 8, 10, 12, 14, 18, 23) with acceptable loading and an internal consistency of 0.76. Subscale 4: Promoting conceptual change in science instruction consists of 8 items (A: 3, 6, 9, 12, 13, 14, 15, 19) with acceptable loading and an internal consistency of 0.59. Three items (A: 8, 11, 20) from the teacher questionnaire did not factor into in any component with acceptable loading values.

A subsample of 63 teachers having useable teacher questionnaires and classroom observations were analyzed using pair-wise correlations. These analyses revealed modest positive correlations between self-report and classroom observations (0.01-0.21).

The moderate relationships among beliefs, perceptions, and actions were not surprising at this early stage of the Science Co-op project. Many teachers were not fully aware of the NSES or state reform principles. We assume that many of their beliefs about the new science reform were likely based on intuitive conceptions developed informally or during professional development activities related to other content areas. The intentions and self-reports of implementation of the reform principle in their teaching were questionable since many of these teachers have not been encouraged by their administrators to be reflective practitioners. The classroom usage of these principles was not expected to provide a full range of ratings on the four dimensions and the

capsule rating since this is the basic problem Science Co-op was designed to address. It is believed that these appraisals will improve and the relationships will become more well-structured as the Science Co-op project unfolds.

Classroom Observation Rubric

Observations of teachers teaching science in actual classrooms was required of the Science Co-op project by NSF's designated project evaluator, Horizon Research Inc. (HRI). NSF requires each LSC project to establish baselines for classroom practices in the teaching of science and has contracted HRI as the central evaluator. Each LSC project is then required to name a Lead Evaluator and to use trained observers to collect observational data on a random sample of teachers in the participating schools. The HRI rubric appears to be based on a specific approach and interpretation of science teaching that has broad appeal and application. The Classroom Observation Rubric developed for Science Co-op is a modification of the HRI rubric that more closely reflects the interactive-constructivist approach described in the "Background" section of this paper (Appendix C). The Science Co-op rubric utilizes a clinical supervision model in observing science teaching in which a pre-observation conference addresses the lesson objectives, plans, and intended strategies and assessment. The observer is required to collect specific information on the structure of the lesson (Design), the teaching performance (Implementation), the subject matter (Science Content) and the instructional climate (Classroom Culture). The post-observation conference is designed to clarify and facilitate the interpretations of the observation. Finally, the observer rates the teaching on the 4 dimensions and makes a global capsule rating based on the descriptors provided by HRI (Appendix C).

Supervisor Ratings

Implementation quality of the Science PALs brand of interactive-constructivist instruction was rated by the school district science coordinator. All K-6 teachers with a science teaching responsibility were rated on an 4-dimension rubric developed to assess the unique features of the Science PALs interactive-constructivist approach. The rubric required the coordinator to assess (1-very weak, 2-weak, 3-satisfactory, 4-strong, 5-very strong) the degree of compliance on dimensions stressed in the reform effort:

1. Depth of content knowledge and content-pedagogical knowledge on science topics taught during the school year.
2. Knowledge of the NSES and focus on fewer, big ideas as a part of a connected whole rather that on coverage of isolated ideas.
3. Use of strategies to access and utilize information on student ideas in planning instruction.
4. Use of strategies to challenge student ideas and to have them reflect on and integrate those ideas into their thinking.
5. Use of strategies that routinely and continuously incorporate children's literature and personal experiences as context for learning science.
6. Use of strategies that promote ongoing, substantive parent involvement in the science instruction.
7. Use of strategies that promote development of reading, writing, and speaking skills in the context of science instruction.
8. Overall rating as a constructivist teacher as defined in the of the Science PALs and Science Co-op projects.

The substantive validity, external validity, structural validity, and reliability of the rubric were established by a series of inquiries utilizing data from the Science PALs project in 1996, 1997, and 1998 (Henriques, 1997; Messick, 1989; Shymansky, et al, 1998, 1999, 2000). First, the substantive validity was established by examining the degree to which dimensions in the rating scale matched both the theoretical and practical assumptions and goals of the project. This match was verified further with correlation studies on the rubric's 7 specific dimensions and global ratings. Correlations between the individual pairs of ratings were between 0.68 and 0.95 for the 1997 ratings and between 0.78 and 0.95 for the 1998 ratings. The external validity was explored by t-test analyses of 128 teachers' ratings (beginning, ending) over a complete Science PALs cycle. Comparisons of the 1996 and the 1997 clustered Science PALs dimension revealed statistically significant predicted improvement ($t=5.0$, p-value <0.001). The structural validity was checked by a series of factor analyses. The 3-factor solution was supportive (component loadings of 0.80 to 0.97) indicating that the 4 dimensions (#3, #4, #5, #6), 3 dimensions (#1, #2, #7), and the global rating (#8) were acting as unified factors.

Reliability was established by the correlation results and by a rate/re-rate analysis of a random sample of teachers. Measures of internal consistency for the 4-dimension cluster were 0.96 (1997 ratings) and 0.97 (1998 ratings). The science coordinator's rating consistency was explored by asking her to rate 235 teachers who teach science in the 16 elementary schools. One week later a random sample of 20 teachers were re-rated by the science coordinator on the ploy that their rating results were lost. The correlations of these paired ratings was 0.95.

Discussion

The vision described in the *National Science Education Standards* (NRC, 1996) is of science teaching that engages all students in a quest for science literacy involving the abilities, critical thinking, and habits-of-mind to construct understanding of the big ideas and unifying concepts of science and the communications to share with and persuade other people about these ideas (Ford, Yore, & Anthony, 1997). The science teaching standards envision the following changes in science instruction (NRC, 1996, p. 52):

Less Emphasis on	More Emphasis on
Treating all students alike and responding to the group as a whole	Understanding and responding to individual students' interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

The question facing every Local Systemic Change project staff intent on effecting the changes described by NRC is how do we know that such changes have occurred or are moving in the right direction? Should we assume that exposure to 130 or more hours of inservice is enough to ensure that project goals will be achieved--that the desired changes in classroom practices and teacher attitudes and perspectives will take place? Or is "time on task" not the powerful factor in

teacher education that it is in student learning? Is it enough to get self-reports from teachers on how they feel about respecting and utilizing students' ideas about science and the importance of evidence in science? Or should we require observable evidence of performance and practice? Can we use student perceptions of the classroom environment as indicators of change or is there simply too much "noise" in such measures? Then there is the whole area of student performance--is the only real true test of a systemic reform effort's success the extent to which students perform better on measures of achievement and attitude? Or is the examination of such measures unfair and the results of such measures uninterpretable?

In this paper we present information on three different instruments developed to provide insight into the degree to which the Science PALs and Science Co-op projects can be claimed to be effective as implied by the NRC changes in emphasis. It should be fairly clear that we are arguing for a multiple-measure documentation strategy that involves multiple forms of data generated by multiple key players (students, teachers, external observers, supervisors). Not mentioned in this paper, but a critical piece of our documentation efforts, is the measure of student achievement with standardized assessment instruments such as Third International Mathematics and Science Study (TIMSS) and States Collaborative on Assessment and State Standards (SCASS). The use of student achievement data to measure reform (teaching) effectiveness is not lacking for critics or controversy. It is noted here though because student achievement measures required elements of the documentation efforts of all NSF systemic change projects.

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Appendix A

Student's Full Name ______________________

School ______________________

Co-op Student Survey (Form A)

This survey is interested in finding out what you think about science, science class, and science careers. Read the sentence. Then mark if you strongly agree, agree, don't know if you agree or disagree, disagree, or strongly disagree with it. All of the sentences in Part 1 deal with science, science at school, science outside of school, and science jobs.

Part 1	Strongly Disagree	Disagree	Don't Know	Agree	Strongly Agree
1. People all over the world do science.	1	2	3	4	5
2. Reading books about science is an important way of learning science.	1	2	3	4	5
3. Science class is exciting.	1	2	3	4	5
4. Science is influenced by what people believe.	1	2	3	4	5
5. Men and women are equally good at science.	1	2	3	4	5
6. Scientists do not always agree with each other.	1	2	3	4	5
7. Science is my favorite subject in school.	1	2	3	4	5
8. People from Africa, Asia, Europe, and the Americas study science.	1	2	3	4	5
9. It is good to question science ideas in advertisements.	1	2	3	4	5
10. What scientists think can change.	1	2	3	4	5
11. Scientists test their ideas through observations and experiments.	1	2	3	4	5
12. I would like to go to a science and technology careers camp.	1	2	3	4	5
13. People have been doing science for a very long time.	1	2	3	4	5

Part 1	Strongly Disagree	Disagree	Don't Know	Agree	Strongly Agree
14. I like science when we read stories.	1	2	3	4	5
15. I like to do science experiments.	1	2	3	4	5
16. A job in science would be fun.	1	2	3	4	5
17. Many individuals have contributed to science.	1	2	3	4	5
18. My parents like it when I am interested in science class.	1	2	3	4	5
19. I like to read books about science.	1	2	3	4	5
20. I look forward to science class.	1	2	3	4	5
21. I would like to have a career in science.	1	2	3	4	5
22. My family likes to visit nature parks and science museums.	1	2	3	4	5
23. I find how-to-do science books interesting.	1	2	3	4	5
24. Many people use science in their jobs.	1	2	3	4	5
25. I like stories about scientists.	1	2	3	4	5
26. I like it when my teacher reads interesting stories to start a science unit.	1	2	3	4	5
27. Scientists expect other scientists to ask how they know something.	1	2	3	4	5
28. Science is important to people and our country.	1	2	3	4	5
29. I like to do science experiments on the weekend.	1	2	3	4	5
30. Men and women can have science jobs.	1	2	3	4	5

Appendix A (Continued)

Part 2 is about your science ideas and science classes this year. Read the sentence. Then decide if it is true almost never, not often, don't know how often, sometime, or almost always.

Part 2	Almost Never	Not Often	Don't Know	Some-times	Almost Always
31. I am given a choice of experiments to do in science class.	1	2	3	4	5
32. When I go home from school, my family asks me what I'm doing in science class.	1	2	3	4	5
33. My teacher helps me when I have trouble with my work.	1	2	3	4	5
34. I am asked by my teacher to think about reasons given by other students.	1	2	3	4	5
35. I carry out experiments to test my ideas.	1	2	3	4	5
36. My teacher tries to answer my questions.	1	2	3	4	5
37. My teacher reads stories about what we are studying.	1	2	3	4	5
38. I am given plenty of time by my teacher to answer questions.	1	2	3	4	5
39. My teacher's questions make me think.	1	2	3	4	5
40. I help decide how class time is used.	1	2	3	4	5
41. I get to test my ideas about science.	1	2	3	4	5
42. I write down my observations and questions.	1	2	3	4	5
43. I help my teacher decide how much time I spend on an activity.	1	2	3	4	5
44. I get a chance to talk with other students about science ideas.	1	2	3	4	5
45. My teacher's questions help me to understand things better.	1	2	3	4	5

Part 2	Almost Never	Not Often	Don't Know	Some-times	Almost Always
46. My teacher talks with my parents about my science class.	1	2	3	4	5
47. My teacher encourages me to share my ideas.	1	2	3	4	5
48. I talk about my science ideas at home.	1	2	3	4	5
49. I discuss ideas with other students in class.	1	2	3	4	5
50. I take my science work home and show it to my family.	1	2	3	4	5
51. My teacher encourages me to share my interests with the class.	1	2	3	4	5
52. I get to find out things on my own.	1	2	3	4	5
53. It is OK to ask for help with ideas that are confusing.	1	2	3	4	5
54. My family is interested in what I think about science.	1	2	3	4	5
55. I get to share my ideas.	1	2	3	4	5
56. When I go to the library, I check on the new science books.	1	2	3	4	5
57. I find science ideas in children's story books.	1	2	3	4	5
58. Scientists collect observations and measures to tell if their idea is on the right track.	1	2	3	4	5
59. I watch science programs on TV, like "Bill Nye the Science Guy".	1	2	3	4	5
60. New jobs in science are part of our science class.	1	2	3	4	5

Student's Full Name ______________________

School ______________________

Co-op Student Survey (Form B)

This survey is interested in finding out what you think about science, science class, and science careers. Read the sentence. Then mark if you strongly agree, agree, don't know if you agree or disagree, disagree, or strongly disagree with it. All of the sentences in Part 1 deal with science, science at school, science outside of school, and science jobs.

Part 1	Strongly Disagree	Disagree	Don't Know	Agree	Strongly Agree
1. I would like to go to a science and technology careers camp.	1	2	3	4	5
2. I like to do science experiments.	1	2	3	4	5
3. Books about people who study and do science are interesting.	1	2	3	4	5
4. Science class is exciting.	1	2	3	4	5
5. I like when my family is interested in what I am doing in science.	1	2	3	4	5
6. A job in science would make me happy.	1	2	3	4	5
7. How-to-do science books are interesting and useful.	1	2	3	4	5
8. A job in science would be fun.	1	2	3	4	5
9. Science fiction stories use science ideas to get your interest.	1	2	3	4	5
10. My parents are more interested in what I am doing in science this year than they were last year.	1	2	3	4	5

Appendix A (Continued)

Part 1	Strongly Disagree	Disagree	Don't Know	Agree	Strongly Agree
11. I like the stories we read in science.	1	2	3	4	5
12. Science ideas have to be tested to be acceptable.	1	2	3	4	5
13. I look forward to science class.	1	2	3	4	5
14. What we know about science now may change in the future.	1	2	3	4	5
15. I am unhappy if we don't do science every day.	1	2	3	4	5
16. Reading books about science is an important way to learn science.	1	2	3	4	5
17. The best science classes are those when we do experiments.	1	2	3	4	5
18. I wish my friends liked science more.	1	2	3	4	5
19. I would like to have a career in science.	1	2	3	4	5
20. Scientists test their ideas through observations and experiments.	1	2	3	4	5
21. My parents like me to safely explore science ideas at home.	1	2	3	4	5
22. I like to read and listen to books about science.	1	2	3	4	5
23. I look forward to science next year.	1	2	3	4	5
24. I like to go to science museums.	1	2	3	4	5
25. What scientists think can change.	1	2	3	4	5
26. The best idea depends on the evidence that supports it.	1	2	3	4	5

Part 1	Strongly Disagree	Disagree	Don't Know	Agree	Strongly Agree
27. Many individuals have contributed to science.	1	2	3	4	5
28. I like to read about science on the internet.	1	2	3	4	5
29. I would like to read about science activities other schools are doing.	1	2	3	4	5
30. Science is important to people.	1	2	3	4	5
31. I like to watch science programs on TV like "Bill Nye the Science Guy."	1	2	3	4	5
32. I would not be willing to work at a science job.	1	2	3	4	5

Part 2 is about your science ideas and science classes this year. Read the sentence. Then decide if it is true almost never, not often, don't know how often, sometime, or almost always.

Part 2	Almost Never	Not Often	Don't Know	Some-times	Almost Always
33. My teacher encourages me to ask questions in science class.	1	2	3	4	5
34. My parents share my science ideas with my teacher.	1	2	3	4	5
35. I get to find out science ideas on my own.	1	2	3	4	5
36. I get to share my ideas in science.	1	2	3	4	5
37. My teacher checks to see that I understand things in science.	1	2	3	4	5
38. I carry out investigations to test my science ideas.	1	2	3	4	5
39. When I go to the library, I pick out science books.	1	2	3	4	5
40. My teacher tries to answer my science questions.	1	2	3	4	5
41. Reading books about science is an important part of our science class.	1	2	3	4	5
42. I discuss science ideas with other students in class.	1	2	3	4	5
43. My teacher writes down my ideas.	1	2	3	4	5
44. I am given plenty of time to answer questions in science.	1	2	3	4	5
45. I get to find out science ideas without my teacher telling me.	1	2	3	4	5
46. I am asked to think about reasons given by other students.	1	2	3	4	5

Part 2	Almost Never	Not Often	Don't Know	Some-times	Almost Always
47. All students are given a chance to answer questions in science.	1	2	3	4	5
48. My family and I go to natural areas, environment reserves, and national parks on our vacations.	1	2	3	4	5
49. It is OK for me to tell my teacher that I don't understand something.	1	2	3	4	5
50. My family and I talk about science at home.	1	2	3	4	5
51. Scientists are required to show evidence for their ideas.	1	2	3	4	5
52. I do science activities with my family at home.	1	2	3	4	5
53. I am asked to explain how I solve problems.	1	2	3	4	5
54. I talk about science at home.	1	2	3	4	5
55. My teacher encourages me to share my ideas.	1	2	3	4	5
56. Before we start a new science topic, my teacher asks what we know.	1	2	3	4	5
57. My family asks what I think about science.	1	2	3	4	5
58. Scientists ask other scientists about how they know something.	1	2	3	4	5
59. Both women and men can have science jobs.	1	2	3	4	5
60. My family and I watch science shows on TV together.	1	2	3	4	5

Part 2	Almost Never	Not Often	Don't Know	Some-times	Almost Always
61. Scientists do experiments to solve problems.	1	2	3	4	5
62. All students are given a chance to contribute to discussions.	1	2	3	4	5
63. People use science in their jobs.	1	2	3	4	5
64. My ideas and suggestions are used in class discussions.	1	2	3	4	5
65. Science jobs are discussed in class.	1	2	3	4	5

Appendix B

SCIENCE CO-OP QUESTIONNAIRE

Part A.

Rate each of the following statements according to the scale: 1-Strongly Disagree; 2-Disagree; 3-Neutral; 4-Agree; 5-Strongly Agree

1. Print materials using mystery, adventure and problem-solving plots should be used as a means of capturing students' interest in science.
2. Science should reflect familiar events and practical applications in the lives of the students.
3. Students should accept scientific explanations of phenomena from a teacher, textbook or other authority figure even if they don't fully understand.
4. The potential interest to the students should be the primary determinant in the selection of print material in a science program.
5. Science textbooks should be replaced by high-interest materials that deal with one or a few topics.
6. Students' alternative interpretations of data from science activities should be emphasized more strongly in print materials used in science.
7. Students' alternative interpretations of data from science activities should be addressed explicitly in class discussions
8. An elementary school teacher should expect some students to continue holding ideas about science that differ from those accepted by the scientific community.
9. Science ideas attributed to popular characters (real and fictional) with whom students can identify are inherently more interesting than when expressed as scientific fact.
10. Most students are willing to replace their own explanations for science phenomena with new explanations, if the new explanations are understandable, justifiable and practical.
11. If a student holds an idea that is different from that accepted by the scientific community, it is best to tell them the correct explanation.
12. The ideas about science that students bring to the classroom are critical to instructional planning.
13. Students' alternative explanations and ideas about science phenomena should be emphasized more strongly in print materials used in science.
14. There should be more emphasis on diagnosing and changing science misconceptions/of naive theories held by students.
15. It is preferable to cover several science topics than to study a few in depth in elementary science.
16. Assessment should de-emphasize summary grading purposes and emphasize more regular attempts to inform learners and teachers.
17. Cross-content (interdisciplinary) connections in science can be valuable to each discipline involved.
18. Cross-content and inquiry teaching take too much time and are inefficient.
19. Inquiry science teaching must be open-ended to be effective.
20. Large-group discussions led by the teacher should not be used in inquiry teaching of science.
21. Student-to-student talk and small-group discussion should be encouraged in science.

22. Self-assessments, peer-evaluations, checklists, investigations and portfolios are as effective as multiple choice tests in science.
23. Informational text, internet sources, expert resource people and direct instruction can be used to consolidate and elaborate science inquiries.
24. Project-based and cooperative learning are critical elements of inquiry science programs.

SCIENCE CO-OP QUESTIONNAIRE

Part B.

Rate each of the following statements according to the scale:
1-Almost Never; 2-Seldom; 3-Sometimes; 4-Often; 5-Almost Always

1. My students are engaged in experiences throughout class time.
2. I challenge all students to establish concepts from evidence gathered during lessons.
3. I use oral and written strategies for students to express their ideas or what they understand about science.
4. I use experiences and situations familiar to the students to introduce hands-on science activities.
5. My students are encouraged to gather evidence to resolve their misconceptions.
6. I use students' curiosity and interests to motivate learning and to make learning relevant.
7. My students initiate activities and investigations in science.
8. My class time focuses on activities that promote students' understanding of concepts rather than rote memory of facts.
9. I have an awareness of my students' understanding of content and modify my lessons when necessary.
10. I see myself as a facilitator of student learning and teaching/learning as a partnership.
11. I use ideas that my own students and other students hold about science to plan my science instruction.
12. I use experiences and situations familiar to the students in discussions following hands-on activities.
13. I discuss the role of student ideas in teaching science with parents of students.
14. I use experiences and situations familiar to the students when interacting with students during hands-on science activities.
15. I formally record and/or file student ideas about science that come to my attention in and out of the classroom.
16. I use exemplars and metaphors that are accurate and relevant to elaborate results from hands-on activities.
17. During lessons I appropriately vary methods to facilitate students' conceptual understanding (e.g., discussion, brainstorming, experiments, questions, log reports, etc.).
18. My lessons are relevant to students' lives.
19. I try to change my lesson plans to pursue student ideas about science that arise during science instruction.

20. I use reading materials to provide an enriched background related to topics being studied in science.
21. I use reading materials to promote students' reflection of their own ideas about science.
22. My students suggest activities throughout class time.
23. As student misconceptions become apparent, I make an effort to help students resolve them.
24. I have students write about their experiences (in and out of the classroom) and their ideas related to topics being studied in science.

Appendix C

Modified LSC Science Classroom Observation Rubric

Ratings for: ______________________ Observer: ______________________

<table>
<tr><th>Overall Dimension</th><th>Specific sub-dimensions</th></tr>
<tr><td>Design: <u>Based on pre-conference and lesson plan</u>
<u>General Descriptor of Session</u>
<u>Category Rating</u>
1 2 3 4 5
Not at all reflective of NSES — Extremely reflective of NSES</td><td>• Purpose and goals 1 2 3 4 5 6 7
• Stressed investigative science 1 2 3 4 5 6 7
• Engaged, challenged and used participants' ideas 1 2 3 4 5 6 7
• Utilized interactions and various groupings 1 2 3 4 5 6 7
• Explored central issue activity 1 2 3 4 5 6 7
• Consolidated ideas and promoted sense-making 1 2 3 4 5 6 7
• Planned assessment 1 2 3 4 5 6 7</td></tr>
<tr><td>Implementation: <u>Based on the classroom observations and post-conference (option)</u>
<u>Category Rating</u>
1 2 3 4 5
Not at all reflective of NSES — Extremely reflective of NSES</td><td>• Demonstrated engage, explore, consolidate, assessment approach 1 2 3 4 5 6 7
• Used questioning to challenge ideas, promote inquiry, support sense making 1 2 3 4 5 6 7
• Utilized students' prior knowledge 1 2 3 4 5 6 7
• Encouraged public discussion of idea 1 2 3 4 5 6 7
• Provided time for private reflection 1 2 3 4 5 6 7
• Paced activities and managed classroom 1 2 3 4 5 6 7</td></tr>
<tr><td>Science Content: <u>Science concepts, processes and habits-of-mind identified in pre-conference and classroom observations</u>
<u>Category Rating</u>
1 2 3 4 5
Not at all reflective of NSES — Extremely reflective of NSES</td><td>• Content was significant and worthwhile 1 2 3 4 5 6 7
• Content was age and developmental appropriate 1 2 3 4 5 6 7
• Students were intellectually engaged 1 2 3 4 5 6 7
• Teacher displayed understanding and confidence 1 2 3 4 5 6 7
• Science presented as dynamic, inquiry, conjecture 1 2 3 4 5 6 7
• Connection made to real-world and cross-disciplines 1 2 3 4 5 6 7</td></tr>
<tr><td>Classroom Culture: <u>Judgement of the appreciation of diversity (gender, race/ethnicity, culture), cooperative/collaborative and intellectual climate</u>
<u>Category Rating</u>
1 2 3 4 5
Interfered with learning — Facilitated learning of all</td><td>• Active participation encouraged and valued 1 2 3 4 5 6 7
• Respects students' ideas, questions, contributions 1 2 3 4 5 6 7
• Interactions reflected collaboration 1 2 3 4 5 6 7
• Encourage students to generate ideas, questions, conjectures, etc. 1 2 3 4 5 6 7
• Intellectual rigor, constructive criticism, challenging ideas and supportive help 1 2 3 4 5 6 7</td></tr>
<tr><td>Capsule: See attached description
1: A B
2:
3: low solid high
4:
5:</td><td>Rationale:</td></tr>
</table>

Capsule Description: Quality of the LSC Lesson

In this final rating of the lesson, consider all available information about the lesson, its context and purpose, and your own judgment of the relative importance of the ratings you have made. Select the capsule description that best characterizes the lesson you observed. Keep in mind that this rating is *not* intended to be an average of the dimension ratings in each category, but should encapsulate your overall assessment of the quality and likely impact of the lesson. Please provide a brief rationale for your final capsule description of the lesson in the space provided.

o **Level 1: Ineffective Instruction**
There is little or no evidence of student thinking or engagement with important ideas of science. Instruction is *unlikely* to enhance students' understanding of the discipline or to develop their capacity to successfully "do" science. Lesson was characterized by either (select one below):

o A. **Passive "Learning"**
Instruction is pedantic and uninspiring. Students are passive recipients of information from the teacher or textbook; material is presented in a way that is inaccessible to many of the students.

o B. **Active for Activity's Sake**
Students are involved in hands-on activities or other individual or group work, but it appears to be activity for activity's sake. Lesson lacks a clear sense of purpose and/or a clear link to conceptual, process or attitude development.

o **Level 2: Elements of Effective Instruction**
Instruction contains some elements of effective practice, but there are *substantial problems* in the design, implementation, content, and/or appropriateness for many students in the class. For example, the content may lack importance and/or appropriateness; instruction may not successfully address the difficulties that many students are experiencing, etc. Overall, the lesson is *quite limited* in its likelihood to enhance students' understanding of the discipline or to develop their capacity to successfully "do" science. Lessons with substantial problems cannot be rated above "Level 2".

o **Level 3: Beginning Stages of Effective Instruction** (Select one below.)
o Low 3 o Solid 3 o High 3
Instruction is purposeful and characterized by quite a few elements of effective practice. Students are, at times, engaged in meaningful work, but there are *some weaknesses* in the design, implementation, or content of instruction. For example, the teacher may short-circuit a planned exploration by telling students what they "should have found"; instruction may not adequately address the needs of a number of students; or the classroom culture may limit the accessibility or effectiveness of the lesson. Overall, the lesson is *somewhat limited* in its likelihood to enhance students' understanding of the discipline or to develop their capacity to successfully "do" science. Lessons with no substantial problems, but some weaknesses are rated "Level 3". The number and importance of weaknesses are used to assign "Low", "Solid", or "High" sub-rating.

o **Level 4: Accomplished, Effective Instruction**
Instruction is purposeful and engaging for most students. Students actively participate in meaningful work (e.g., investigations, teacher presentations, discussions with each other or the teacher, reading, writing). The lesson is well-designed and the teacher implements it well, but adaptation of content or pedagogy in response to student needs and interests is limited. Instruction is *quite likely* to enhance most students' understanding of the discipline and to develop their capacity to successfully "do" science.

- **Level 5: Exemplary Instruction**
  Instruction is purposeful and all students are highly engaged most or all of the time in meaningful work (e.g., investigation, teacher presentations, discussions with each other or the teacher, reading, writing). The lesson is well-designed and artfully implemented, with flexibility and responsiveness to students' needs and interests. Instruction is *highly likely* to enhance most students' understanding of the discipline and to develop their capacity to successfully "do" science. Few lessons well be rated "Level 5", since this rating is reserved to Artfully teaching of technically and theoretically sound lessons described by "Level 4".

Revised Horizon Research, Inc. (2000)

CONSTRUCTING INVESTIGATIONS: COLLABORATIVE PROFESSIONAL DEVELOPMENT IN TECHNOLOGY AND SCIENCE EDUCATION

Lawrence B. Flick, Oregon State University
Walter Gamble, Association of General Contractors
Dick O'Connor, Oregon Building Congress

The purpose of this project was to pilot a professional development program for 12 teachers of general science (grade 5 through high school). The outcome was to generate standards-based classroom tasks based on construction engineering problems. The project used professionals in construction engineering in collaboration with science teachers and a science educator, to design and present tasks through hands-on activities derived from problems in real construction projects. Follow-up efforts supported teachers in developing model lessons that emphasized construction engineering principles using tasks aligned with national and state science standards. The purpose of this paper is to analyze evaluation data in terms of a model for professional development in teaching to benchmarks in technology as stated in Benchmarks for Science Literacy (AAAS, 1993). Figure A outlines the major principles as discussed in Science for All Americans (AAAS, 1990) a companion document to the AAAS Benchmarks.

This project was a collaboration among the Oregon Building Congress (OBC), the OSU Construction Engineering Management (CEM) program, and the Department of Science and Mathematics Education. CEM is under the Department of Civil, Construction, and Environmental Engineering. It is the only CEM program in Oregon. OBC is the school-to-work arm of Oregon Association of General Contractors (AGC). Its major goal is to show pre-college students and their teachers the opportunities and challenges in the construction industry. OBC has been successfully running five workshops a year for math teachers. This collaboration

extended this program to science teachers. The project was completely funded by AGC members and will cost about $60,000 in direct support from AGC and in-kind support from participating contractors.

Motivation for this project stemmed from the need to increase the pool of high-skilled workers for the building trades and construction management positions. AGC was also concerned that public perception of the construction industry is often limited to experience of delays on highways and controversy over urban and rural development. Through this program AGC would like teachers to develop a more balanced view of the construction industry's goals and methods.

From the perspective of education in science, there is the concern that higher standards may generate a greater disparity of achievement between advantaged and disadvantaged learners (Zeichner, 1995). State implementation of national science education reform goals challenge teachers to develop critical thinking in all students to support understanding and conduct of scientific inquiry (AAAS, 1993; NRC, 1996; ODE, 2000). There is a risk that emphasis on the more abstract concepts of science inquiry adds a layer of greater sophistication in learning science that will exact a heavier cost from the wide range of students who typically opt out of science and engineering studies during high school (McNeil, 2000). Construction engineering problems not only provide a vehicle for promoting benchmark principles of technology but also a way to foster abstract thinking in active, concrete contexts.

Notable among students opting out of science are students with educational disadvantages such as poverty or membership in a cultural or language minority. Haberman (1995) notes that teachers who are successful in improving the achievement of disadvantaged students do so by

showing the value of knowledge for enriching and promoting the lives of students. These teachers do not exhort learning on the basis that it is a stepping stone to further education. This goal is hard to envision for many students especially those with few economic means and no role models for how to learn. Rather they show the value of learning for what it allows the student to do: learning is doing; learning is making; learning is meaningful action (Haberman; 1995). Teacher knowledge of construction engineering problems can help them meet this need.

A corner stone of Project 2061 of the Association for the Advancement of Science is that Learning science concepts should not be a task that discriminates among learners. Science for All Americans (AAAS, 1990) makes clear that scientific literacy should be a basic in education. All learners will not learn the concepts at the same level of sophistication but all learners can understand and apply these concepts in significant and meaningful contexts. Science is accessible for student-constructed investigations, grounded in problems that are highly visible in the student's world with variables that can be directly manipulated. Scholarship on teaching disadvantaged learners indicate that student engagement with activities based on student-generated questions supports learning among children of poverty (Means & Knapp, 1991; Means, Chelmer, & Knapp, 1991). Traditional instruction for disadvantaged students that focus on remediation of basic skills to the exclusion of problems and issues based on students' everyday experiences and that provoke reflection and inquiry, deprive these students of a higher quality education (Haberman, 1995; Haberman, 1991). Construction sites are common and highly visible. Heightening teacher awareness of what goes in to building things offers another tool for teachers to motivate students and expand awareness of career opportunities that can be pursued with a high school education as well as at the college level.

Technology Education

From the perspective of science education this project was motivated by the need to address the relationship among science, technology, and engineering. Teaching about the disciplines of science has shared the spotlight with teaching about technology to the extent that technologies have aided the pursuit of scientific understanding. Telescopes and microscopes are examined because they extend human senses and promote scientific investigations of the very distant or the very small.

But technologies play a much larger role in the lives of people because they are the interface between scientific knowledge and day-to-day activity. As such, knowledge about the development and use of technologies is as important to working and living as is knowledge of scientific principles. In follows then, that "Technology education is every bit as important as science education. Like science, a technological thread weaves through the very fiber of our lives…" (Loucks-Horsely, et al., 1990, p. 28). Project 2061 of the Association for the Advancement of Science recognized this when they organized Science for All Americans and Benchmarks for Scientific Literacy around three fundamental concepts: (a) the nature of science, (b) the nature of mathematics, and (c) the nature of technology. The first two concepts have received the lion's share of instructional time with the nature of technology playing a very restricted role.

To understand the purpose of the project described in this report, we must reflect on the ubiquitous term 'technology.' In the contemporary vernacular of science education, the word "technology" generally means "computer technologies." The explosion of digital technology has created a revolution similar to the "hands-on" movement of the 1960s. The flexibility, speed, and

storage capacity of contemporary desktop computers is causing science educators to redefine the meaning of hands-on experience and rethink the traditional process of teaching (Flick and Bell, 2000). This meaning is associated with an important and pervasive segment of technology but it has narrowed the understanding of technology. A more comprehensive account of what people should know about technology is stated in Benchmarks for Scientific Literacy (AAAS, 1993) (see Figure A). The AAAS perspective implies curricula and teaching strategies that lead students to understand technologies as human response to solving problems in their lives. One important set of problems is the scientific investigation of the natural world. However, there are many problems that are more immediate and compelling for students and people in general. Virtually every significant problem in modern life has a technological component (e.g. pollution, safe transportation, safe food and water supply, and safe, efficient construction).

Workshop activities of this project lead teachers to question and probe for understanding both the natural world and what Science for All Americans calls the "built environment." Follow-up discussions with each activity pointed out the broad range of thinking skills critical to science and life in general embodied in these construction engineering problems including information gathering (e.g. observing, inferring, and experimenting), decision-making, and general problem-solving. Further, understanding the nature of technology in the context of a means-end analysis, means understanding how people work together to solve problems, assess risk, negotiate trade-offs, and determine cost-effectiveness.

The threads of technology and science cross, twist, separate, and come back together as they weave through life. It was a goal of this project to understand teaching about technology and science as naturally related and mutually supportive. Knowledge of principles of optics

supports understanding uses of telescopes while using a telescope provides experiences that support understanding the behavior of light, lenses, and mirrors. Activities in this project linked construction engineering problems directly to principles of science consistent with national and state standards. Using construction problems as one example of how to teach about technology, each day's task involved not only a hands-on problem but illustrations of the science principles involved.

Program Objectives

The central goal of the program was to increase teacher knowledgeable of the construction industry so that students would develop a broader understanding of the industry, its engineering challenges, and career opportunities. To accomplish this goal, program activities provided teachers with engaging, hands-on experiences in construction engineering problems that at the same time provided a significant curricular resource for implementing standards-based instruction. The specific program objectives were:

- To improve teacher knowledge of construction engineering problems and their application for developing student understanding of the relationships between science and technology through a 5-day workshop on construction engineering problems that involve hands-on model building and field trips to construction sites.
- To introduce teachers to the field of construction engineering management and the construction industry as important career opportunities for a wide range of students whose goals include bachelors degrees, associate degrees, or apprenticeship programs.
- To develop pedagogical skills in designing standards-based instruction and incorporating field trips to local construction sites that support learning of concepts in science and technology.

- To provide feedback and support over the academic year by follow-through experiences that involve (a) opportunities for professional networking with workshop participants and building contractors and (b) facilitating opportunities to conduct student field trips to local and regional construction sites.

Project Description

A five-day, intensive workshop in July, 2000 targeted teachers of general science, grades 5-12. Fifteen participants were solicited from school districts primarily in urban areas along the I-5 corridor. Based on the evaluation data of this pilot project, the Oregon Building Congress (OBC) and Association of General Contractors (AGC) plan to offer five summer 2001 workshops.

The pilot group of 12 teachers learned construction engineering skills through problems and hands-on activities presented by professional engineers and contractors. Instructors were selected by the director of the Oregon State University Construction Engineering Management program and president of the Association of General Contractors, from AGC members.

The professional technical education coordinator from a regional education service district (ESD), was a partner in developing and validating the content of this workshop. He and a panel of teachers met twice to review workshop logistics and content. All districts with participating teachers matched the OBC stipend of $250 to provide teachers with a $500 summer stipend to design construction engineering-based science instruction.

The author lead and coordinated the education content of the summer and data collection for evaluation. The summer workshop was structured around four elements: (a) identification of standards-based science content and aspects of scientific inquiry, (b) contractor presentation of

hands-on activities, (c) visits to construction sites, and (d) sharing of lesson design techniques and modeling of teaching strategies.

The author and teachers from the ESD worked with contractors to relate hands-on activities and construction problems to stand standards in science content and inquiry. Educators also identified how these activities could be used to articulate across benchmark years to help participating teachers understand how to build science and inquiry competence in students (Schauble, Klopfer, and Raghavan, 1991).

Data for evaluation are outlined in Table 1. These data were compiled beginning with the design of the workshop and collected through the first semester of the following academic year. Evaluation data was organized to evaluate the program's effectiveness in supporting teacher design of standards-based instruction and improving knowledge of career and educational opportunities for a broad range of students in science. Preliminary recommendations were made for professional development for science teachers relative to engineering and construction applications.

Table 1

Program Objectives and Data Sources for Evaluation

Objective	Evaluation
Knowledge of construction engineering problems; and their application for developing student understanding of the nature of scientific inquiry.	▫ Field notes and interviews during workshop. ▫ Teacher-designed units of instruction
Designing standards-based instruction and incorporating field trips to local construction sites.	▫ Teacher-designed units of instruction ▫ AGC records of scheduled field trips ▫ Selected classroom observations and video tape records.
Field of construction engineering management and the construction industry as important career opportunities for students.	▫ Survey on knowledge of opportunities for students in construction industry. ▫ Selected follow-up interviews.
Professional networking.	▪ AGC records of contacts with teachers, schedule of field trips, email logs, number of teachers completing instructional designs, number of teachers observed. ▪ Evaluation of OBC web site against objectives of professional development program, frequency of use by participants.

Selection of Participants

Participants were selected through vocational technical specialists in educational service districts in the area. A profile of the school represented by participating teachers in contained in Table 2.

Table 2

Profile of Schools Represented by Participants in the Summer Workshop

School	Enrollment	Class Size (Math)	Student / Teacher Ratio	% Free or Reduced Lunch	% Minority	% Urban	Median Household Income
Dist. A HS	1498	29	22.0	20.0	10.6	44.7	27,421
Dist. B MS	207	22	18.8	19.3	1.9	0.0	31,755
Dist. B HS	234	18	18.0	19.2	5.6	0.0	31,755
Dist. C HS	1235	30	24.2	15.0	10.3	72.3	25,791
Dist. D HS1	1404	-	22.9	20.0	15.3	93.1	31,826
Dist. D HS2	1343	-	23.0	8.4	10.5	93.1	31,826
Dist. E MS	315	21	14.3	45.4	5.7	0.0	20,316
Dist. F Elem	481	25.3	20.5	17.1	6.2	91.5	27,377

Source: Oregon Department of Education Database Initiative Project for 1999-2000 available from http://dbi.ode.state.or.us/ and US School District Data Book Profiles for 1989-1990 available from http://govinfo.library.orst.edu/.

Knowledge Of Construction Engineering and Careers

A detailed description of summer workshop activities is contained in Appendix A. The program was analyzed using criteria from the "partnerships" model of professional development (Loucks-Horsley, 1998, pp. 132-141). Presenters were volunteers from the membership of AGC. All were professional contractors and two were graduates of the Construction Engineering Management program at OSU. Teachers, educational service district vocational-technical specialists, and a science educator from OSU met with the Executive Director of OBC and professional contractors. From this series of meetings, activities were discussed and eventually selected and refined for presentation at the summer workshops.

All ideas were judged against the Oregon Science Content Standards and Benchmarks for Scientific Literacy (AAAS, 1983) (see Figure 1). Input from teachers and the science educator provided feedback and suggestions for making the workshop experience interactive. Each presentation involved a hands on activity and demonstrations. Under the direction of the science educator, a component of each day's session was a time for the teachers to debrief and consider curricular implications for their classrooms. Discussions also included reflection on national and state standards.

Figure 1

Project 2061*: Science for All Americans

Nature of Technology

- Engineers use knowledge of science and technology, together with strategies of design, to
- solve practical problems.
- Anticipating the effects of technology is as important as advancing its capabilities.
- The essence of engineering is design under constraint: physical laws; economic; political; ecological; ethical; personnel to operate, maintain; and repair, and the need to test performance.
- Most applications of technology are in the form of systems. All systems involve control: getting feedback, making logical decisions, and activating changes in the system.
- Complex systems usually involve layers of control where coordination is important and ultimately allowing humans to make key decisions.
- All technologies have side effects, some desirable, some undesirable.
- Risk analysis is complex because decisions are always based on incomplete information. Human judgments are sometimes at odds with objective data.
- All systems can fail but hedges against failure can reduce risk such as over designing - making something stronger, bigger, or faster than necessary; redundancy or backup; and engineering the probability of safest failures happening first.
- Increases in human population and the accumulated knowledge and creativity have resulted in providing adequate support for the majority of people on earth but at the expense of and increased risk to other forms of life.
- Technology influences history and history influences technological developments.
- The economic, social, and political consequences of technology imposes restrictions on openness.
- Good decisions about the use or development of technology depends upon seeking answers to key questions such as alternatives, cost/benefit and to whom or for whom, risk, and safe disposal or recycling of materials and waste.

* Project 2061 of the American Association for the Advancement of Science also produced Benchmarks for science literacy. New York: Oxford University Press, 1993.

While the intent was to include specific curriculum design sessions as part of the week's activities, it was generally left to the individual teachers to consider these issues on their own and bring ideas to the next day's session. Therefore during the week, there was only minimal time devoted to developing curriculum and instruction from the workshop. Knowledge of construction engineering problems was assessed more directly from follow-up interviews conducted in December.

The nine classroom teachers attended the workshop were interviewed by telephone by the science educator. The interview protocol shown in Figure 2 was designed by the science educator and validated by the Executive Director of OBC and a member of AGC who were familiar with the goals of the project, Oregon Science Content Standards and Benchmarks for Scientific Literacy. They judged the protocol to be consistent with workshop objectives and practical for a 15-minute telephone interview.

Figure 2

Follow-up Interview Protocol Conducted with Participating Teachers

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Summer Workshop
What specific construction engineering problems do you remember from the summer workshop?
Describe how you use (or plan to use) construction engineering (type) problems in your teaching.
Have you taken or plan to take any field trip(s) as a result of the summer workshop?
What are career opportunities for high school graduates based on what you learned from the summer workshop?
If you have prepared instructional materials based on construction engineering problems, if you are willing to share them at this time.

Technology and Science Education
What meaning do you attach to the term 'technology' for the purposes of instruction?
What should students learn about technology?
What do you see as the relationship between teaching about technology and science education?

The teachers remembered all five activities the four field trips. In addition, the teachers described presentations by both guest speakers. Time did not allow for each teacher to name all 11 elements of the workshop (see Figure 3), however all named at least four elements and the purpose of each. This feedback did not develop an in-depth discussion of the engineering problems presented.

Figure 3

Project Components

Hands-on activities

- Buoyancy - based on lakeside construction problem
- Pascal's Principle – based on hydraulics of construction machinery
- Model road construction – manufactured rock
- Concrete strength test – materials used to strengthen concrete
- Materials science classroom – activities involving plastics and other polymers
- "How things get built" – general contracting model

Field Trips

- Construction Company – aggregate mining; construction machines
- Waste Treatment Plant - city
- Wave Action Research facility – OSU
- Building tour of OSU campus – HVAC; electrical distribution; heat generation

Speakers

- Earthquake construction
- Construction Engineering Management Program

The teachers did not express any new knowledge about careers in construction. They felt they were already familiar with the skilled trades and the jobs of contractors. One said that they learned how contractors work in specific segments of the business and that all are not completely general contractors. Another was interested in how much scheduling a contractor must do to

coordinate work at a construction site. While most teachers did not learn about new career opportunities, three said that the experience would help them talk about these careers more meaningfully to their students.

Teachers said that it would be difficult for them to generate authentic construction activities related to classroom instruction. They felt they would need considerable professional help to guide students in projects. The middle school teacher from District B (see Table 2) said that there was an area around their school that they hoped to develop in some way, perhaps as a nature trail. Based on knowledge from the summer workshop, he thought this would make a good construction project. However, his awareness of construction problems involving water drainage, soil compaction, and design considerations to use the space appropriately, pose major challenges. He has been in contact with a contractor from the workshop to begin putting an planning group together to link the project to science teaching.

A middle school teacher from District E (see Table 2) was enlightened by how much need there was for qualified workers in the construction industry. His district has been hard hit by the loss of jobs in the logging industry and many students live in poverty. In his school, 45% of the students are eligible for free or reduced cost lunch. Because students beyond elementary school become conscious of their poverty, many do not sign up for this program and this statistic usually underestimates the poverty level in a school. For students who would otherwise not pursue further education, this teacher is trying to help expose students to the education and training opportunities in construction trades.

Field trips

Even though AGC is prepared to pay for bus transportation to construction sites, no teacher has taken advantage of this offer. Two teachers are considering trips to near by construction sites, one to a local airport and another to a stone quarry. Two other teachers see opportunities to observe construction in action either near their school building or on the building itself. The summer workshop experience has made them aware of the potential offered by visits to such sites even if they have not been able to develop curricular plans to support these visits.

Part of the preparation and debriefing of field trips during the summer were discussions of how community and expertise could be used and integrated with instruction. These discussions attempted to expand thinking about the use of community expertise beyond field trips and guest speakers (Flick, et al., 1985). Teachers were encouraged to think about community experts as resources for materials and ideas for classroom instruction. The workshop itself was an example of how community experts could provide teachers with ideas for instruction without actually visiting the classroom. The teacher from District B is developing construction expertise as a resource base for a classroom project. The teacher from District E is considering how to utilize the resources of AGC to support summer activities for the disadvantaged students in his building.

Designing standards-based instruction

Teachers discussed examples of instruction during the interviews. Three actually submitted instructional materials designed with construction problems in mind. Only two of the nine teachers interviewed had not done anything with the topic of construction engineering since the workshop. They both expressed vague plans for the spring.

The two middle school teachers from District E worked up plans to teach buoyancy based on the workshop presentation. Their plans however, were direct teaching of the science principles of density, mass/weight, volume displacement in water, and specific gravity. The construction problem context was not developed in the materials they designed nor in their interviews. The impression was that they would use the construction problem as an interesting example to talk about rather than a context for application and investigation.

The high school teacher from District D developed an involved investigation based on the presentation about cement. In this case, he made a direct application of the workshop activity that tested the strength of cement when mixed with various additives. In this case, the teacher was testing the cement as a bridge by applying various amounts of weight.

Teachers in Districts B, D, and E all described attempts to have students apply organizational and planning skills to solve complex problems using a model presented during the summer. Teachers from Districts B and D both gave students the fabrication problem from the summer workshop. Students were given roles to play in a general contracting environment and were to construct a box from a given set of specifications. The summer task involved a group of adults for about 30 minutes. Its goal was to simulate problems of communication, coordination, and group dynamics. The issues were subtle and complex. The District B teacher used four, 50-minute class periods with his middle school students. He implied a focused effort at addressing state and national standards. However it was difficult and would need much revising for next year. The district D teacher said that his students high school finished the box in one 90-minute period. His objectives were not made as clear.

Teaching about Technology

Preliminary results of interview analysis concerning teaching about technology are contained in the following excerpts.

What meaning do you attach to the term 'technology' for the purposes of instruction?

District B: Any tool you use to get something done; used to be video and computers; a ruler is technology; kids think computers and software.

District C: All the hands on activities, woodshop, metal shop, crafts, auto mechanics (name for old industrial ed.). Phone, TV, VCR, Computer station in classroom.

District D: Most say computers... But in science it has meant equipment of all kinds... all kinds of machines and tools.

District E: Construction; putting things together more efficiently and better; show how women worked in WWII in construction and they can work in these jobs today; girl who wants to be a fighter pilot.

District F: Anything that is a tool, that will help you do something better or faster; history and science, technology is changing.

What should students learn about technology?

District B: Don't be afraid of it, jump in; I feel a gap as a teacher, there are smart and dumb ways to do that; schools oriented toward high tech; technology (computers) is rushing past us;... hard to define, hard to assess what kids really need to know! Does a kid really need to know how a Vernier probe works in order to use a CBL to take a reading on pH? Or should she just use litmus paper? Is the litmus paper "technology".

District C: Applied science. Pure science – research and studying the environment to push back the frontier of knowledge. But knowledge must be applied, e.g. engineers solving problems that students see in their everyday lives.

District D: How to use it. The good and bad of technology – what is better what is a problem? Tradeoffs – some times get lost in meaning of results, like calculators. Some teachers have gone back to doing some things like graphing by hand to help kids process information.

District E: Kids should see that there is a chance for a career in unions/apprenticeship programs without going to college; knowledge about technology in construction will help them get jobs.

District F: Something that can help them; developed over time; something we use, adapt, invent; High tech is not necessarily useful; power goes out; gas prices go up tech has a price; impact environment by products.

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Appendix A

Description of Summer Workshop published in Construction News Update, September 11, 2000, p. 24, Supplement to the Daily Journal of Commerce

School To Career: Science Summer Workshop at Oregon State University

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In late July, the Oregon Building Congress (OBC), AGC Oregon-Columbia Chapter, and the Oregon State University Construction Environmental and Engineering (CEE) Department hosted the first-ever Science Summer Workshop in Construction at Apperson Hall on the OSU campus. Ten teachers attended, representing grades 5 through 12 from around the state.

The workshop, the brainchild of OBC, was developed and produced by members of the Construction Management Education Council (CMEC) of AGC. Planning for the event began in the fall of last year and proceeded through a series of meetings leading up to the workshop itself. Guiding this effort were the Certificate of Initial Mastery benchmarks at the 8th and 10th grade levels. Our educator advisors informed us early in the planning that incorporating these benchmarks with the objectives of the workshop would greatly increase its value for teachers.

The week demonstrated the relevance of general science principles such as soil density, concrete, hydraulics and buoyancy to the construction world. One objective of the week was to give the teachers lesson plans they could use in their own classrooms. On day one, Steve Malany (OSU/CEM Class of 1990) from P&C Construction did a demonstration with concrete and had the teachers make a variety of samples using different mixes of aggregates and cement. On the last day of the workshop, these test samples were given stress tests to determine which combination

held up the best. The teachers were intrigued at the wide variance in stress tolerance and the importance of getting the right mixture, because failure to do so can lead to costly removal of newly placed concrete and disruption of the construction schedule.

That afternoon was filled with a most informative experience provided by Morse Brothers at its Tangent headquarters and Corvallis mine. Eileen Shufelt guided the group through a variety of activities including an introduction to Morse Brothers “Let's Rock” classroom program. John Johnson, fluid power expert at Morse Brothers, did several excellent demonstrations on hydraulics power transfers and braking systems. John showed how hydraulics is used in road equipment and passed out samples of hydraulic parts. The field trip to the Corvallis mine site gave the teachers the "on-the-ground" experience of aggregate development, processing and delivery (There's no substitute for the roar of a 3-ton cement truck!).

Walt Gamble (OSU/CEM Class of 1969), of Gamble Construction Services, presented a great lesson plan around Blaise Pascal's law of pressure. Using only a wooden table, eight plastic waste paper baskets, four trash bags, four hoses and about two feet of tape, Walt gave a graphic demonstration of how Pascal's law is applied in hydraulics. By nesting the wastebaskets between a deflated bag under each leg, and then having teachers blow through the hoses, they were able to lift a maximum weight of 1500 pounds. We did this with the author sitting on the table while the teachers were blowing, and as if by a miracle, up in the air I went! It was a gravity-defying act for sure!

What followed Walt's presentation was something unexpected: teachers began to discuss among themselves how to make “Walt's Hydraulic Machine” more efficient. This was a classic instance of entrepreneurial and technological abilities coming together to make a better product. It

was also an example of what John Dewey called reflective thinking. The striking thing to me was how Walt took an abstract law and gave it a practical application that could be used in any classroom, and that the practical application generated higher level thinking. Too often educational pedagogy stays at the knowledge and comprehension levels and too frequently excludes application, analysis, synthesis and evaluation. If we are to follow Alfred North Whitehead's maxim that we should teach a few things well, we should then strive to have students working at these higher levels in most of their course work.

Another major theme of the week was water. At dinner on the first night, Nason McCullough, a member of the OSU/CEE staff, delivered an informative lecture on liquefaction and how it was a major cause of destruction in the Kobe earthquake. Liquefaction occurs when the soil is saturated with water. If this condition is present when an earthquake strikes, building structures will either sink or totally collapse. McCullough gave a wonderful example of this by running water from the ground up in a tube of rocks and sand. He then placed a weight on top of the sand, and then hit the tube with a rubber hammer, simulating an earthquake. The weight totally disappeared into the sand. I thought of all those ocean front houses!

Another day we traveled to the Wave Lab on the OSU Campus. Professor Chuck Sollitt, director of the lab, demonstrated how it is used to simulate a variety of different wave effects and how they will impact various shoreline conditions and structures. This lab is one of the few in the country, and Dr. Sollitt hopes to obtain a National Science Foundation grant to enlarge it. We also traveled to the wastewater reclamation center in Corvallis.

Bob Pyritz (OSU/CEM Class of 1972) from Western Paving demonstrated how roads are built using various grades of aggregates. It was intriguing to the teachers how important the type

of rock was to ensure proper compaction and the compressive strength of a road. It was also fascinating to learn how a lack of the proper type of aggregates can lead to poor roads, as is the case in parts of central Oregon. (Frankly, it never dawned on me to think that different parts of the country have widely varying aggregate qualities for road building. All roads may look the same, but it is what's underneath that determines their quality.) Bob also gave extensive commentary on the regulatory hurdles facing a road builder. These remarks could well form great lesson plans on the costs and benefits of regulations.

Rich Tolvstad (OSU/CEM Class of 1987) of RT and Associates, Inc. presented the teachers with the principles of buoyancy and Archimedes' Law that "the buoyant force on a body immersed in fluid is equal to the weight of the fluid displaced by that object." I could probably repeat this over and over and never really get it. Rich used an actual construction situation to illustrate this principle. He was contracted to do extensive remodeling of a dock and install an underwater equipment vault for a Lake Oswego property owner. The construction materials would have to be carried by barge across the lake at a significant cost per hour. Key to Rich's successful bid was how long he would need to use the barge, which was determined by how much it could carry, which was determined by applying Archimedes principle. Rich provided the teachers with information on the density and specific gravity of various substances, and then had the teachers use glass jars to simulate barges and decide how much weight they could carry and still remain afloat.

Helping to put the whole construction process into context, Walt Gamble presented "How Things Get Built." Here teachers formed four groups simulating the Design/ Engineering, Contractor, Supplier and Subcontractor segments of the industry. The chore was to build

something useful within an estimated time and budget with only the resources provided. Walt simulated real construction situations by throwing in several wrinkles (suppliers delivering only after a certain time, staplers containing only three staples, engineers refusing to respond to questions until they returned to their office, subcontractors working with one hand tied behind their backs). Teachers were most impressed by the amount of coordination involved in a construction project.

John Koch, assistant director of Building and Facilities and a licensed architect, gave the teachers a tour of the buildings on the OSU campus. As our focus was on the heating and ventilation of the buildings, we spent a good amount of time in underground tunnels. One above-ground experience that was a delight occurred when John introduced our science teachers to the Linus Pauling Exhibit at the Harmony Library. The curator of the exhibit was kind enough to go into the vault to show the teachers Pauling's two Nobel prizes, one in Chemistry in 1934 and one for Peace, in 1962, as well as one original manuscript of his work. Pauling, an OSU graduate, is the only person to win two unshared Nobel prizes.

Ending the week, Professor David Rogge gave an overview of the Construction Engineering Management Program at Oregon State. Professor Rogge has taken over as head of the CEM department from Hal Pritchett. A special thanks also goes to Larry Flick, Professor of Math and Science Education and Andy Brickman, Director of the Material Sciences Lab. Larry provided important curriculum guidance to the teachers during the week, and Andy was a most accommodating director, allowing us free use of his lab.

UNIVERSITY SCIENCE MAJORS IN COLLABORATIVE PARTNERSHIPS WITH ELEMENTARY TEACHERS: INQUIRY BASED TEACHING AND LEARNING

Donna L. Ross, San Diego State University
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The Crisis in Elementary School Science

Unfortunately, the current state of elementary science education remains bleak. Science instruction continues to remain a low priority in elementary schools in the United States, particularly in California. Many teachers hesitate to incorporate science into the curriculum because they lack confidence in their ability to teach science. This is due, in part, to their own lack of science content knowledge (Wenner, 1993). Most teachers have taken several college-level courses, but these classes are typically lecture-based and do not prepare teachers to synthesize and teach science in a developmentally appropriate manner (McLoughlin & Dana, 1999). Even in instances when teachers are excited about including science in the curriculum, there are constraints to teaching elementary science. These constraints include lack of time, facilities, supplies and equipment (Abel & Roth, 1992). In addition, when science is taught, teachers frequently avoid hands-on lessons because these activities are deemed to be too much work, too time intensive, and too dependent on materials that are usually in short supply or lacking (Sumrall, 1997).

Many attempts have been made to improve elementary science instruction. One of the most promising is the redevelopment of undergraduate science courses to align with the National Science Education Standards (NCR, 1996) and to blend pedagogical content knowledge within content courses (Mason, 1999; McLoughlin & Dana, 1999). Unfortunately,

it is unlikely this will become the norm any time soon.

Effective Professional Development

As we anticipate and explore long-term changes in science teaching for future teachers, effective professional development for practicing teachers needs to be developed and implemented. Haney and Lumpe (1995) argue that science education does not have a comprehensive framework for teacher professional development. Their recommendations include long-term training, fostering active teaching and learning, emphasizing science in the elementary grades, and providing context-specific training (Haney & Lumpe, 1995). These suggestions are supported by Loucks-Horsley (1998) who also identifies the importance of including science content in professional development. Currently, professional development programs for teachers in science education tend to be short-term, emphasize science for upper grades, and are not context-specific.

PISCES Project

This study examines the development, implementation, and early results of the Partnerships to Involve the Scientific Community in Elementary Schools (PISCES) program. The PISCES project is a comprehensive approach to professional development, utilizing university science graduate students, university and community scientists, and educators to enhance elementary science. The PISCES project is designed to address the constraints to

quality elementary science instruction, as identified in the research literature and by local classroom teachers, through quality, long-term professional development.

A needs assessment was conducted prior to implementation of the PISCES project. One hundred and four local teachers and nine administrators responded. Over half of the teachers reported teaching science two hours or less per week. Seventy-five teachers agreed or strongly agreed they would like someone knowledgeable about science to assist them in their teaching. Nearly 80% of the teachers indicated they would like to know strategies for integrating science with other disciplines, especially with the major focus on literacy and mathematics instruction. The top three needs identified were science instructional support, alignment with content standards, and science content training. The PISCES project was designed to help meet these needs.

PISCES Science Students

One of the primary goals of the project is to place people who have strong science content knowledge into elementary classrooms on a long-term basis to provide instructional support to the classroom teachers. The PISCES project, funded by NSF and local sources, provides fellowship support to graduate and upper-level undergraduate science students from several local universities to work in elementary classrooms. These science students, known as PISCES Science Corps Members, provide content knowledge and classroom assistance as they work with the teachers. Corps Members are placed in two elementary classrooms during each eight-week cycle throughout the academic year. Their 15-20 hours of work each week focus on

planning and presenting hands-on science lessons with the classroom teachers. Science Corps Members complete bi-weekly reports, weekly journals, yearly interviews, and meet with a faculty member weekly. During the 1999-2000 academic year, there were 11 students supported. The project was expanded to 20 students for the 2000-2001 academic year.

PISCES Professional Development

The PISCES project provides professional development to the Science Corps through a university seminar to prepare and support them. The seminar is designed to socialize Corps Members to the culture of the elementary school, provide them with a background for addressing the National Science Education Standards (NRC, 1996) and the inquiry approach to science, offer a forum for discussing pedagogical theory and strategies, and prepare them to use popular curricula materials such as FOSS (Full Option Science System) and STC (Science and Technology for Children) kits.

In addition to the professional development offered to the Science Corps Members, there are workshops held several times a year for the classroom teachers to learn strategies and content for inquiry-based science instruction. These workshops include field trips that allow teachers to interact with local scientists conducting research. The strength of these workshops is that the Corps Members are also involved, so collaborative teams gain the same knowledge and experiences.

PISCES Resources and Materials

The PISCES Project provides FOSS and STC kits to the teachers for the duration of the unit. After the completion of a unit, the kit is returned and refurbished before being sent out to another teacher. Corps Members add to the kits by providing additional content and teaching resources through their own research on the science topics. This aspect of the project aims to relieve some of the logistical constraints identified in the study by Sumrall (1997).

The final component of the project is to develop science curricula and resources to incorporate current research by local scientists, who are working to better understand global change. Study sites are located in California, Mexico, and the northern slope of Alaska. Throughout the project, real-time data is available to elementary classes. A subset of the Science Corps travels to the study sites to conduct research and develop appropriate curricula, as well as work with local classroom teachers to incorporate it into the elementary classroom curriculum.

Initial Findings

Early results (n=36) demonstrate that the professional development has helped the teachers to be more confident in their knowledge of inquiry approaches to teaching, their ability to integrate science with other disciplines, and the effective use of hands-on materials. Teachers indicate high levels of satisfaction with the project and are eager to remain with the project during subsequent years. One of their recommendations was that the Corps Members

extend their time in an individual classroom from two months to three. This was implemented during September, 2000. Elementary students expressed their satisfaction with the scientists in their journal entries and at school functions. Before beginning a journal entry on what she had learned about electricity, one elementary student wrote:

> "This might not be a very positive thing at the beginning of a piece of writing, but let me start this reflection by saying that I don't like science very much. So when you announced the PISCES project I didn't exactly jump for joy. But as the scientists started coming in, I realized that I had under-estimated science. In electricity, I've leaned a lot. Since I've never really liked science, I've never given myself a chance to really learn anything...."

Unanticipated results included the higher level of confidence that the teachers gained as they sought to defend science instruction to their administrators who questioned the use of time spent on science instruction when the state and district emphases are on literacy and mathematics.

The Science Corps Members also reported highly positive experiences. In interviews, fellows indicated that their communication skills had improved, they had a much better understanding of the rewards and challenges involved in teaching elementary school, their college teaching (teaching assistantships) had changed to more closely resemble an inquiry approach, and some were considering careers in education, or at least including out-reach education in their future plans. One of the Corps stated, "I've learned a lot. I teach in a different manner, not the way I've been taught recently. I don't just stand up there and tell them.... I now want to teach high school. I've made a lot of contacts and I've also increased my content knowledge." Another Member found that "it makes you think about all of the little

aspects of science. The parts you take for granted, now I've learned to put it all together." All of the Corps Members who have not graduated are planning to continue in the program.

Future Plans

The PISCES project has increased in size. There are now over 60 classroom teachers involved, 20 science Corps members, and more than 1,200 elementary students who have participated. Data collection continues, including interviews, surveys, journals, and classroom observations. The ultimate goal of the PISCES project is to increase quality science education in elementary schools after the Corps members have moved on to other schools. As the teachers become more comfortable with teaching science, they will begin to take the lead in the lessons, and finally, will teach the units without the PICSES Corps. In fact, we have already seen a spill-over to other classrooms as a result of the PISCES project. The project hopes to find that the support of materials, resources, content knowledge, assistance in the classroom, as well as the development of a community of teachers and scientists dedicated to excellence in science education will move teachers beyond the perceived constraints. Administrators, science educators and local business and industry personnel are key to the institutionalization of such efforts.

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THE RELATIONSHIP BETWEEN ATTITUDE TOWARD SCIENCE WITH ENROLLMENT IN A 4x4 BLOCK SCHEDULE

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The focus of this study was to examine a group of rural high school students' attitude toward science at the beginning and end of a 90-day semester. With the growing use of one-semester courses in many schools, it is worth exploring the effects of this alternative schedule on students enrolled in these courses.

Research about Attitude Toward Science

Research into various aspects of attitudes toward science, which has been defined as a general and enduring positive or negative feeling about science (Koballa & Crawley, 1985), has contributed a significant amount of literature throughout the past several decades. A great deal of this research stemmed from the large amounts of data taken from the 1976-77 NAEP survey of nine, thirteen, and seventeen-year-olds, and from the 1982 study of approximately 4500 North Carolina students by Simpson and Troost. These and other studies of attitudes have led researchers in science education to the understanding that there are many variables that correlate with attitudes about science such as achievement (Schibeci, 1984), behavior (Shrigley, 1990), and grade level (Simpson & Oliver, 1985). Still, another goal for some science educators has been to find ways to foster positive attitudes toward science as an attempt to create a more scientifically literate populace (Simpson, Koballa, Oliver, & Crawley, 1994; Hufstedler & Lungenberg, 1980).

One major branch of research into student attitudes toward science has been to document a relevant correlation between these attitudes and student achievement. The common-sense argument leads us to believe that students who have a positive feeling toward science would engage in behavior that leads to higher achievement. However, there has been very little evidence to show that this relationship exists, at least not to a large degree (Steinkamp & Maehr, 1983; Talton & Simpson, 1987). Although correlations have been found, they tend to be extremely weak, accounting for approximately 10-18 percent of the variance in achievement. More problematic in this attempt to discover if affective means lead to achievement ends is the work of Rennie and Punch (1991), which showed that a student's attitude toward science is more strongly tied to previous achievement than that in the future. In other words, students enjoy science because they do well in the subject. Success leads to positive feelings more often than the reverse.

These findings do not bode well for establishing a linear path for greater achievement through increasing positive student attitudes. However, should that be the only reason that attitudes are of importance? Those interested solely in demonstrating that students are learning by pointing to higher test scores would most likely affirm. But what makes an individual want to continue with their involvement in science? Simpson et al. (1994) continues these pertinent questions, "What is it about our educational experience that significantly changes a young person? Why do some graduates become intelligent consumers of science and some do not? Why do some people immerse themselves in science while others shun the scientific enterprise? Why do some students seem to click into place while others wander outside the mainstream of science?" (p.

211). From a teacher's perspective, helping students to develop positive attitudes about science is, in and of itself, a worthwhile goal of science education. With that idea in mind, what aspects of a science education have been shown to demonstrate some relationship with a student's attitude toward science?

One of the first goals of the 1982 Simpson and Troost study was to develop a deeper understanding of the factors that lead to higher levels of commitment to science among adolescent students, with an ultimate goal of learning how to increase this commitment. Several researchers were able to specifically identify what some of these factors were and determined to what extent they were responsible for causing variations in students' attitudes toward science. Various published studies grew out of the data collected from the work of Simpson and Troost. Of the various factors under study, classroom factors were responsible for between 46-73 percent of the variance in these attitudes (Simpson & Oliver, 1990; Talton & Simpson, 1986; Talton & Simpson, 1987). Data from the same study also showed that student attitudes dropped as they aged, (Simpson & Oliver, 1990) along with their motivation to achieve. Particular aspects of a student's overall attitude, such as attitudes toward curriculum, the science teacher, and the physical environment, were found to significantly drop over time as a student progresses through school. Other factors, such as the classroom emotional climate and science self-attitude, were found to be somewhat more stable. Gender differences were also identified, regardless of grade level (Simpson & Oliver, 1990). For instance, males were found to differ significantly from females in terms of anxiety (less) during science class, science self concept, and in their general attitude toward science. Female students were found to have higher scores in their attitude of the physical environment of the

science class. These gender differences were still significant when the different ability levels of the students were taken into account (Simpson & Oliver, 1985). It was also found that a student's attitude toward science declines throughout the course of the school year (Cannon & Simpson, 1985).

Among the more important findings of these studies was the ability to predict with high accuracy the likelihood of a student discontinuing his or her attempts to pursue science at a level beyond what was required in the high school curriculum (Simpson & Oliver, 1990). The scores of three affective subscales were 90 % accurate in predicting science enrollment during the last two years in high school in one group of students. Providing learning environments conducive to the development of positive attitudes seems to be critical in keeping pupils in the sciences. The structure of the school day is one aspect of the learning environment that has been modified for a variety of reasons.

Research on Block Scheduling

One of the most recent trends in secondary schools during the last decade has been the transition from a traditional six or seven period day to some form of an extended-time block schedule. One of the popular forms of the block schedule has been the 4x4 block, in which students attend four 90-minute classes each day that meet for one semester only (Hurley, 1997). Students are able to take eight different courses over the school year under this plan. Marshak (1997) states that one of the reasons for this change is to "escape from 'the box' and to create structures for high school based on some very different understandings of human development, learning and teaching, the nature and structure of knowledge, and the cultural and social realities of the present, as well as the

future, as well as expectations for the future, than were commonly held in 1920 or 1970" (p. xiv).

Others have provided more pragmatic reasons for the switch to the block schedule. The school operating under this format will benefit from decreased movement of students between classes throughout the day, fewer administrative tasks faced by teachers, better student-teacher ratios, more planning time, promotion of hands-on and cooperative learning, and increased use of a variety of teaching strategies (Queen & Isenhour, 1999). The prevailing wisdom is that teachers will be unable to teach through lecture or other teacher-centered methods for the entirety of the 90-minute block without the use of a variety of exercises and experiences throughout the duration of each class. Students should become more active participants in their education as classrooms become more centered on the student and less so on the teacher. Action researchers concluded in one study of students on the block schedule that the key to student enjoyment of their classes was activity (Marshak, 1997).

Studies focusing on the effects of the implementation of this new form of scheduling have supported the ideas that teachers would use a greater array of techniques and that students would become more active in learning. After the implementation of the block schedule at a school in Southeastern Ohio, 97 % of teachers and 77 % of students stated that teachers supervised a greater variety of projects than under the traditional schedule (Eineder & Bishop, 1997). The same Ohio school reported that 91 percent of teachers and 77 % of students felt cooperative learning was more common during the longer class periods. Students from another pair of Ohio schools were commonly found reporting that extended classes were more interesting and enjoyable (Wronkovich, Hess,

& Robinson, 1997). Hurley (1997) reported student support for the block schedule due to increased lab activities and group work. Much, although not all, of the research provides evidence that teachers become more student-centered in their methodologies while teaching in the 4x4 block schedule.

After changing from the traditional schedule, the emotional climate of the classroom has seemed to improve, both for students and teachers. The increased contact time each day has resulted in an increased number of students having more positive attitudes about their relationships with teachers (Eineder & Bishop, 1997) and with teachers feeling more positive about their relationship with students (Mistretta & Polansky, 1997). With the classroom more focused on the activity of the student, the teacher is better able to help those students who need it the most. Hurley (1997) reported in his qualitative study that students perceived more one-on-one time available with their teachers during class. With all of the positive changes in the atmosphere of the classroom, the overall atmosphere of the school experiences a subtle change for the better. Teachers in a California study concur with these findings that both teachers and students seem more relaxed under the block schedule because of fewer classes each day (Staunton & Adams, 1997). In addition, the school as a whole becomes less hectic due to the classroom climate becoming much more relaxed.

Up to this point, almost all research concerning the block schedule has been either open-ended, qualitative surveys and questionnaires, or focused on the correlational relationship between the block schedule and achievement. With these preliminary studies on the effects of the block schedule reporting many positive results, especially in terms of how students feel about the classroom environment, it is worth questioning how the block

schedule may affect the attitude toward science that a student may hold. Attempts to establish the relationship between a student's attitude toward the classroom environment and attitude toward science have been supported by Talton and Simpson (1987) who found that student attitudes toward the classroom environment predicted between 56 to 61 percent of the variance in a student's attitude toward science. Talton and Simpson highlighted the significance of their data:

> The importance of classroom environment in relation to student attitudes toward science has been underscored in this study. This is itself is significant. If science curricula and activities are developed that enhance student interest in science, and if classrooms are made stimulating, supportive environments in which students may question and develop their interests in science, an important educational goal will have been achieved. Student commitment to and interest in science will help facilitate these students, as adults, to make enlightened decisions on science-related governmental policies and social issues. (p. 524)

The importance of the classroom environment on the student's attitude toward science is very evident.

With these relationships established, this investigation was designed to describe the relationship of enrollment in a block schedule with a student's attitude toward science and to determine whether or not these attitudes change throughout the course of the semester, as was previously found with students enrolled in a traditional school schedule. Few studies have inquired into this relationship, although Bateson (1990) concluded that there was no significant difference in affective scores of students in British Columbia using data from the Third Provincial Assessment of Science. This study only used data

from the end of the course, so there was no investigation as to how affective domains changed. As more is understood about how this type of scheduling affects a student's attitudes about science, better decisions can be made in determining whether a switch to this format of scheduling is worthwhile.

Research Questions

The following research questions were developed to examine the relationships between classroom environment and affective learning outcomes over time:

1. Is there a correlation between classroom environment variables and attitude toward science?
2. Is there a change in attitude toward science and other classroom environment attitudes by students enrolled in semesterized block schedule science courses?

Method

Sample

This investigation was designed as a pilot study to determine changes in attitude toward science and attitude toward other classroom environment variables by science students at the beginning and end of a course operating under the 4x4 block schedule. Students (n = 121) from a small high school in eastern Georgia volunteered to participate in the study. The high school is the only public school in the county, has an enrollment between 700 and 800 students, and serves an adolescent population that is approximately 79% African-American and 19% White. Economically, over 80% of the students in the high school are eligible for either federally subsidized free or reduced lunches. This study included three different classrooms and represented ten different classes (including

Physical Science, Biology, Chemistry, and Applied Biology and Chemistry) that were taught during the spring semester of 2000. Each of these classrooms also used student teachers during the year, which increased the number of instructors involved in this study to six.

Of the 121 students who participated in the study, six did not identify their gender during the first administration of the questionnaire. Of the remaining 115 students, 77 were female (67 percent) and 38 were male (33 percent). Eight students did not identify their grade level. Of the 113 remaining, 53 were in the 9th grade (47 percent), 30 were in the 10th grade (26.5 percent), and 30 were in the 11th/12th grade (26.5 percent). During the second administration, 110 students participated, with a loss of 11 students from the first administration. Several students neglected to identify gender and/or grade level, but the percentages of the subgroups during the second administration were essentially the same as in the first.

Instrument

The instrument used in the study was developed by Simpson and Troost (1982) to measure attitudes toward science and other variables associated with school science by middle and high school students. The instrument was designed with short and direct statements (Table 1) with a five-response Likert-type scale.

Table 1.

Items Comprising Instrument Subscales

Attitude toward Science	1. Science is fun. 5. I have good feelings toward science. 8. I enjoy science courses. 15. I really like science. 18. I would enjoy being a scientist.

	21. I think scientists are neat people. 24. Everyone should learn about science.
Emotional climate of the science classroom	2. I feel nervous in science class. 9. I usually look forward to my science class. 19. This class is a good place.
Science curriculum	3. We do a lot of fun activities in science class. 10. We learn about important things in science class. 17. We cover interesting topics in science class. 23. I like our science textbook.
Science teacher	4. My science teacher encourages me to learn more science. 11. I enjoy talking to my science teacher after class. 14. My science teacher makes good plans for us. 20. Sometimes my science teacher makes me feel dumb. 22. My science teacher expects me to make good grades.
Anxiety	6. Science makes me feel as though I am lost in a jungle. 12. My mind goes blank when I am doing science. 16. Science tests make me nervous. 25. I would probably not do well in science in college.
Science self-concept	7. I consider myself a good science student. 13. I think I am capable of becoming a doctor or an engineer.

Note: Numbers preceding items indicate position of item in the instrument.

A response of five indicated strong agreement, and a response of one indicated strong disagreement. The original instrument contained 15 subscales that were used to examine attitudes toward science, classroom, school environment, home environment, and "self". For this study only six of the above subscales were selected for examination. The subscales that most directly related to the students' learning environment and science as a

subject were chosen for this study. Subscales relating to family interest in science, friends' interest in science, and attitude toward school were not used as a part of this study. There was one attitude toward science scale, three classroom environment subscales, and two "self" subscales. The classroom environment scales examined attitudes about the emotional climate of the science classroom, the science curriculum, and the science teacher. The "self" subscales examined attitudes about science self-concept, and anxiety.

Data Collection Procedures

The attitude instrument was given during the spring semester of the 1999-2000 school year at the beginning and end of the course. During the first administration 121 students responded to the questionnaire. This number dropped to 110 for the second administration due to student loss over time from transfer, absenteeism, or other various reasons. Informal communication with and observation of the teachers in this study were conducted for the purpose of verifying the use of a variety of techniques in the classroom.

Data Analysis

The data were analyzed using SPSS 10.0 software (1999). All statements that were worded negatively were changed during the input of data. For example, "1" was changed to "5", and "2" was changed to "4". Descriptive statistics, such as mean and standard deviation, were then compiled. Data sets were grouped into several categories in order to make comparisons between gender and grade. For each student, the various statements from the questionnaire were summed in each subscale. Since there were seven statements in the Attitude Toward Science subscale, students could score a minimum of seven and a maximum of 35. Other subscales had different

maximum/minimum values depending upon the number of items in the scale. Questionnaires with incomplete responses in any items in a subscale were not used in the data analysis. From these descriptives, it was concluded that parametric tests could be used for comparison of groups.

To compare each subscale, Pearson correlation coefficients were calculated using the total data collected. For group comparison, t tests were used to compare individual items and individual subscales at both times for total population, both genders, and each grade level. T-tests were also used to compare each grade and gender group to one another after each administration. Alpha reliability was calculated for each subscale.

Results

Reliability

Of the six subscales used in the study, acceptable alpha reliability was found in all but one (Table 2).

Table 2.

Reliability of Subscales

	Number of Items On Subscale	Alpha Reliability
Attitude Toward Science	7	.8730
Emotional Climate of The Classroom	3	.5280
Attitude Toward the Science Curriculum	4	.7579
Attitude Toward the Science Teacher	5	.6763
Science Anxiety	4	.1601
Science Self-Concept	2	.4251
Emotion Scale with	2	.7070

Item 2 Omitted		
Anxiety Scale with Item 25 Omitted	3	.6624

The Attitude Toward Science subscale, consisting of the largest number of items, had the highest reliability (0.8730), while the 4-item Science Anxiety subscale had the lowest alpha (0.1601). However, one item of the anxiety subscale was most responsible for this low value. The item, "I probably would not do well if I took science in college" was significantly lower than the other three items in the subscale. With the removal of this item from the group, the alpha value increased to 0.6624 with the other three items. The subscale for Emotional Climate of the Classroom was also lower than the others (0.5280), although there were only three items in the group. Again, one item, "I feel nervous in science class", was significantly higher (more positive) than the others. The removal of this item from the scale increased reliability to 0.7070.

Correlations

Each of the six subscales correlated significantly ($p<.01$) with each of the other groups (Table 3).

Table 3.

Correlation Coefficients (Pearson) for Subscales

	Curriculum	Emotion	Teacher	Self-Concept	Anxiety
Attitude Toward Science	.655	.675	.500	.585	.424
Attitude Toward The Science Curriculum	---	.572	.634	.477	.319
Emotional Climate of The Science Classroom	---	---	.517	.675	.367
Attitude Toward the Teacher	---	---	---	.353	.306
Science	---	---	---	---	.543

Self-Concept						

Note. All values are significant at p<.01

Of these, three had a Pearson coefficient greater than 0.65: Attitude Toward Science – Science Curriculum (0.655), Attitude Toward Science – Emotional Climate of the Classroom (0.675), and Emotional Climate of the Classroom – Science Self-Concept (0.675). The lowest Pearson coefficients were found between Attitude Toward the Teacher – Science Anxiety (0.306) and Attitude Toward Curriculum – Science Anxiety (0.319). The Attitude Toward Science was found to have the highest correlations of all groups, with the least significant relationship found with Science Anxiety, although the Pearson value for this was still significant (0.424).

Grade Levels

Students in the ninth grade reported the most positive overall scores during the first administration of the instrument (Table 4).

Table 4.

Time 1 Mean Scores (Standard Deviation)

	Total	Males	Females	9th	10th	11th/12th
Attitude toward science						
1.	3.04(1.27)	3.13(1.07)	3.00(1.19)	3.07(1.11)	2.90(1.14)	3.03(1.25)
5.	3.03(1.22)	3.05(1.35)	2.97(1.15)	3.02(1.31)	2.90(1.22)	3.10(1.13)
8.	3.02(1.25)	3.03(1.20)	2.90(1.32)	2.98(1.23)	3.00(1.29)	3.10(1.21)
15.	2.74(1.28)	3.43(1.29)	3.20(1.26)	2.67(1.23)	2.61(1.36)	2.73(1.28)
18.	2.07(1.22)	2.14(1.16)	1.96(1.27)	2.06(1.14)	1.90(1.17)	2.10(1.37)
21.	3.20(1.24)	3.10(1.15)	3.20(1.29)	3.05a(1.25)	3.00x (1.31)	3.66(1.14)
24.	3.71(1.15)	3.80(0.99)	3.67(1.24)	3.64(1.22)	3.41x (1.18)	4.14(0.95)
Emotional climate						
2.	4.36(0.88)	4.55(0.64)	4.26(0.98)	4.46A(0.75)	4.03(1.13)	4.52(0.98)
9.	2.96(1.27)	3.03(1.20)	2.90(1.32)	3.19A(1.18)	2.58(1.33)	2.83(1.32)
19.	3.15(1.30)	3.37(1.26)	3.05(1.32)	3.35C(1.29)	2.48x(1.15)	3.30(1.32)
Science curriculum						
3.	3.27(1.19)	3.58(1.22)	3.14(1.18)	3.63C(1.14)	2.61x(1.17)	3.20(1.06)
10..	3.81(1.21)	4.08*(0.88)	3.65(1.35)	4.20C(0.79)	3.16(1.46)	3.70(1.34)
17.	3.28(1.26)	3.43(1.26)	3.20(1.30)	3.52A(1.21)	2.79(1.45)	3.28(1.16)
23.	2.61(1.20)	2.33(1.12)	2.69(1.23)	2.56(1.30)	2.48(1.27)	2.79(1.05)

Science teacher						
4.	3.59(1.21)	3.89*(1.09)	3.44(1.25)	3.85C(1.07)	3.10(1.40)	3.43(1.14)
11.	2.43(1.10)	2.46(1.04)	2.39(1.05)	2.46(1.13)	2.14(1.13)	2.55(1.05)
14.	3.58(1.03)	3.74(0.72)	3.53(1.17)	3.81C(0.87)	3.07(1.20)	3.53(1.01)
20.	3.99(1.23)	3.83(1.23)	4.00(1.25)	4.12(1.14)	3.69(1.44)	4.03(1.18)
22.	4.18(0.89)	4.13(0.82)	4.24(0.91)	4.26(0.73)	4.07(1.13)	4.21(0.86)
Anxiety						
6.	3.66(1.39)	3.87(1.23)	3.53(1.44)	3.80(1.16)	3.58(1.52)	3.70(1.58)
12.	3.56(1.32)	3.37(1.42)	3.64(1.25)	3.70(1.33)	3.23(1.43)	3.67(1.21)
16.	3.03(1.44)	2.71(1.35)	3.13(1.46)	2.98(1.46)	2.94(1.41)	3.37(1.40)
25.	2.82(1.43)	3.13(1.33)	2.71(1.45)	3.19a(1.40)	2.72(1.28)	2.41(1.55)
Science self concept						
7.	3.50(1.26)	3.32(1.40)	3.56(1.19)	3.33a(1.33)	3.50(1.20)	3.87(1.14)
13.	2.98(1.24)	2.84(1.15)	3.06(1.29)	2.74(1.25)	3.19(1.31)	3.10(1.14)

Notes.
* Mean is significantly different from females at the 5% level
(A) Mean is significantly different from 10th grade at the 5% level
(B) Mean is significantly different from 10th grade at the 2% level
(C) Mean is significantly different from 10th grade at the 1% level
(a) Mean is significantly different from 11th / 12th grade at the 5% level
(b) Mean is significantly different from 11th / 12th grade at the 2% level
(c) Mean is significantly different from 11th / 12th grade at the 1% level
(x) Mean is significantly different from 11th / 12th grade at the 5% level
(y) Mean is significantly different from 11th / 12th grade at the 2% level
(z) Mean is significantly different from 11th / 12th grade at the 1% level

Numbers in the left margin correspond with statements on Table 1.

In particular, they gave the most positive responses to the Emotion, Curriculum, Teacher, and Anxiety scales, although they had the least positive beginning score in the Self-concept scale. Of note was the decline in all scales over the course of the semester, with the exception of the Attitude Toward Science scale, which rose minimally (Figure 1).

Figure 1.

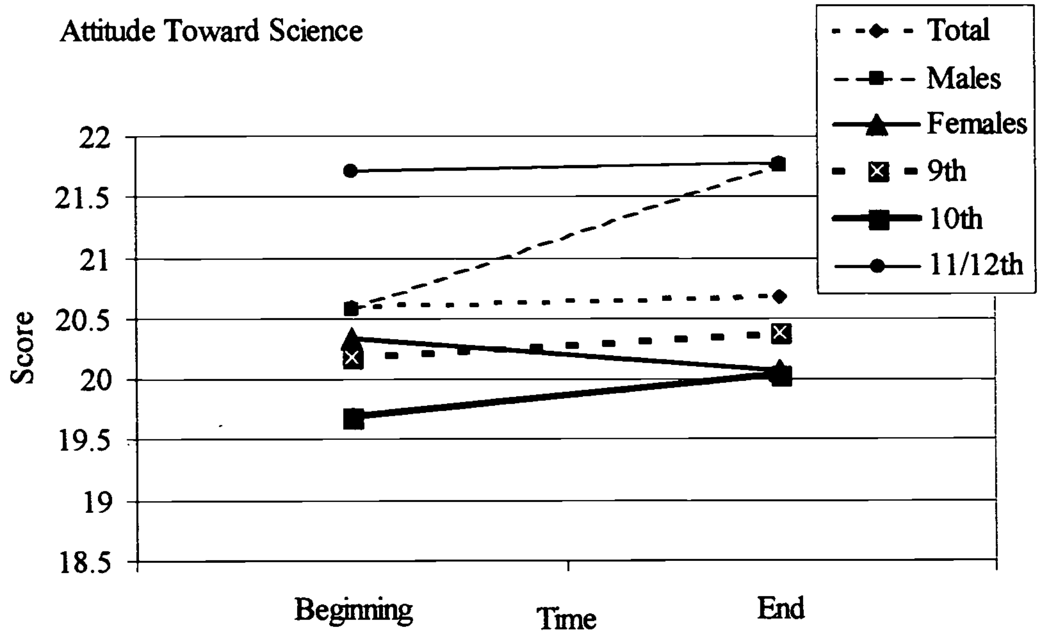

Figure 1. Change in attitude toward science by group over time. The maximum score was 35 and the minimum was 7.

The only significant change that was found was in the decrease reported on the Emotional Climate of the Classroom (Figure 2) scale ($p<.001$).

Figure 2

Emotional Climate of the Classroom

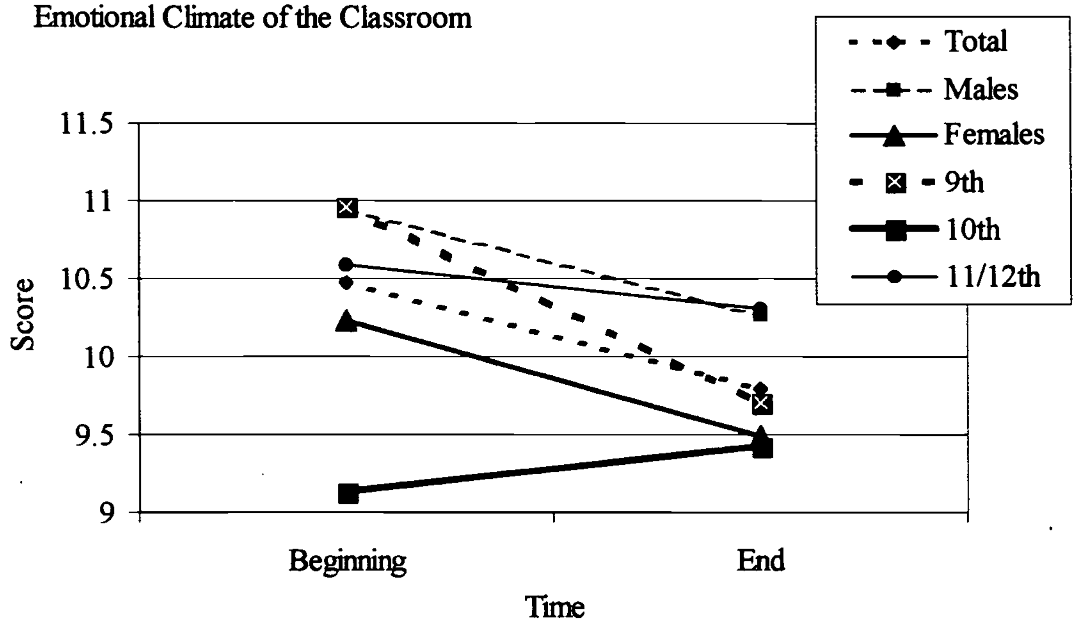

Figure 2. Change in the emotional climate of the classroom by group over time. The maximum score was 21 and the minimum was 3.

Also, students in Grade 9 had significant (p<.05) decreases in four items (#2, 9, 19, & 20) over the course of the semester (see Table 1 for these items). Three of these four were found in the Emotional Climate of the Classroom subscale.

Grade ten students reported the lowest overall scores at both the beginning and end of the semester. Scores for these students remained fairly constant throughout the school year, although four of the six scales (attitude toward science, emotion, curriculum, and teacher) became more positive, while the other two (anxiety and self-concept) decreased. None of the changes were significant. One item, "Science makes me feel as if I were lost in a jungle" was the only item with a significant (p<.025) decrease.

Students in grades eleven and twelve were pooled together during data collection because each group was fairly small, and they tended to be enrolled in classes together. For example, Grade 9 students were mostly enrolled in physical science, while Grade 10 students in the study were enrolled in biology. Students in the highest two grades made up the enrollment in three other science classes. In other words, there were no courses taught that were either purely Grade 11 or Grade 12.

These students reported the highest ending scores of all groups (Table 5).

Table 5.

Time 2 Mean Scores (Standard Deviation)

	Total	Males	Females	9th	10th	11th/12th
Attitude toward science						
1.	2.97(1.20)	2.95(1.29)	2.99(1.16)	2.92(1.21)	2.68x(1.28)	3.31(1.07)
5.	2.86(1.21)	3.16(1.21)	2.70(1.18)	2.85(1.15)	2.68(1.28)	3.03(1.27)
8.	2.87(1.24)	2.97(1.14)	2.81(1.28)	2.89(1.25)	2.68(1.16)	3.03(1.30)
15.	2.68(1.35)	2.81(1.39)	2.59(1.36)	2.64(1.33)	2.50(1.43)	2.93(1.33)
18.	2.15(1.30)	2.56*(1.50)	1.93(1.14)	2.12(1.22)	2.26(1.43)	2.10(1.37)
21.	3.37(1.28)	3.47(1.16)	3.32(1.34)	3.37(1.32)	3.30(1.41)	3.46(1.10)
24.	3.64(1.33)	3.67(1.35)	3.61(1.35)	3.52(1.41)	3.61(1.52)	3.89(0.95)
Emotional climate						
2.	3.96(1.17)	3.95(1.20)	3.94(1.18)	4.00(1.21)	3.93(1.27)	3.93(1.03)
9.	2.73(1.29)	2.92(1.40)	2.64(1.24)	2.67(1.25)	2.68(1.36)	2.86(1.33)
19.	3.08(1.31)	3.41*(1.40)	2.87(1.22)	2.98(1.37)	2.82x(1.31)	3.52(1.12)
Science curriculum						
3.	3.20(1.22)	3.17(1.22)	3.23(1.21)	3.30(1.20)	3.07(1.39)	3.14(1.09)
10.	3.35(1.10)	3.43(1.22)	3.30(1.00)	3.33(1.11)	3.36(1.26)	3.38(0.88)
17.	3.35(1.19)	3.43(1.17)	3.30(1.18)	3.33(1.23)	3.36(1.28)	3.38(1.05)
23.	2.68(1.21)	2.86(1.24)	2.59(1.19)	2.54(1.24)	2.57(1.26)	3.04(1.03)
Science teacher						
4.	3.63(1.23)	3.86(1.20)	3.49(1.24)	3.60(1.21)	3.43(1.40)	3.89(1.07)
11.	2.35(1.21)	2.59(1.30)	2.24(1.16)	2.25(1.23)	2.32(1.16)	2.54(1.26)
14.	3.31(1.18)	3.41(1.09)	3.30(1.22)	3.42(1.20)	3.21(1.23)	3.21(1.11)
20.	3.42(1.61)	3.53(1.57)	3.41(1.65)	3.52(1.58)	3.14(1.71)	3.50(1.62)
22.	4.29(0.93)	4.31(0.89)	4.29(0.95)	4.21(1.01)	4.32(1.02)	4.39(0.63)
Anxiety						
6.	3.29(1.47)	3.76**(1.34)	3.04(1.49)	3.55B(1.35)	2.68(1.49)	3.38(1.57)
12.	3.30(1.46)	3.92***(1.30)	3.01(1.45)	3.45(1.54)	3.18(1.39)	3.14(1.41)
16.	3.03(1.47)	3.24(1.30)	2.84(1.53)	2.92(1.40)	2.68x(1.52)	3.55(1.45)
25.	2.87(1.55)	2.83(1.63)	2.86(1.53)	2.67(1.50)	3.36(1.73)	2.75(1.38)
Science self concept						
7.	3.48(1.30)	3.43(1.35)	3.46(1.28)	3.35(1.52)	3.43(1.10)	3.76(1.02)
13.	2.62(1.48)	2.62(1.46)	2.56(1.47)	2.77(1.53)	2.61(1.42)	2.34(1.47)

Notes.

* Mean is significantly different from females at the 5% level
** Mean is significantly different from females at the 2% level
*** Mean is significantly different from females at the 1% level
(B) Mean is significantly different from 10^{th} grade at the 2% level
(x) Mean is significantly different from 11^{th} / 12^{th} grade at the 5% level

Like Grade 10 students, there was no change found from the beginning to the end of the semester. Of the six subscales, four declined, but only minimally. The exception to this was in the Science self-concept (Figure 3) which, although not significant (p<.143) was more substantial than the others.

Figure 3.

Science Self-Concept

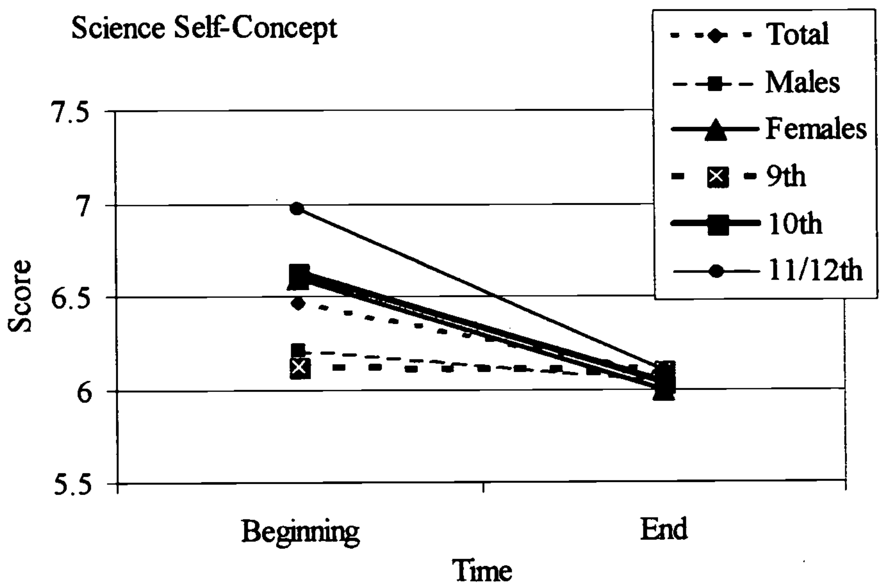

Figure 3. Change in students' science self-concept by group over time. The maximum score was 10 and the minimum was 2.

Scores for the Attitude Toward Science and Emotional Climate of the Classroom increased, but neither was significant. Only one item, "I feel nervous in science class" was found to have a significant decrease (p<.05).

In comparing each grade level to one another, several significant differences were found at the beginning of the semester, although none were found at the end. Grade 9 students were more positive than Grade 10 students in the Emotional Climate of the Classroom, Science Curriculum, and the Science Teacher. Students in grades eleven and twelve were more positive than Grade 10 students, as well, in the Emotional Climate of the Classroom.

Gender

Male students reported the most positive scores on four of the subscales at the beginning of the semester and on all scales at the end of the semester in comparison with females. There were no significant changes found between the ends of the semester in any of the subscales. Three scales (attitude toward science, curriculum, and anxiety) became more positive while the other three (emotion, teacher, and self-concept) each became more negative.

Female students reported higher values on Science Anxiety (meaning they actually had less anxiety) and in Science Self-Concept when the semester began. All scores dropped during the course of the semester, although only the anxiety subscale (Figure 4) was found to have a significant decrease.

Figure 4.

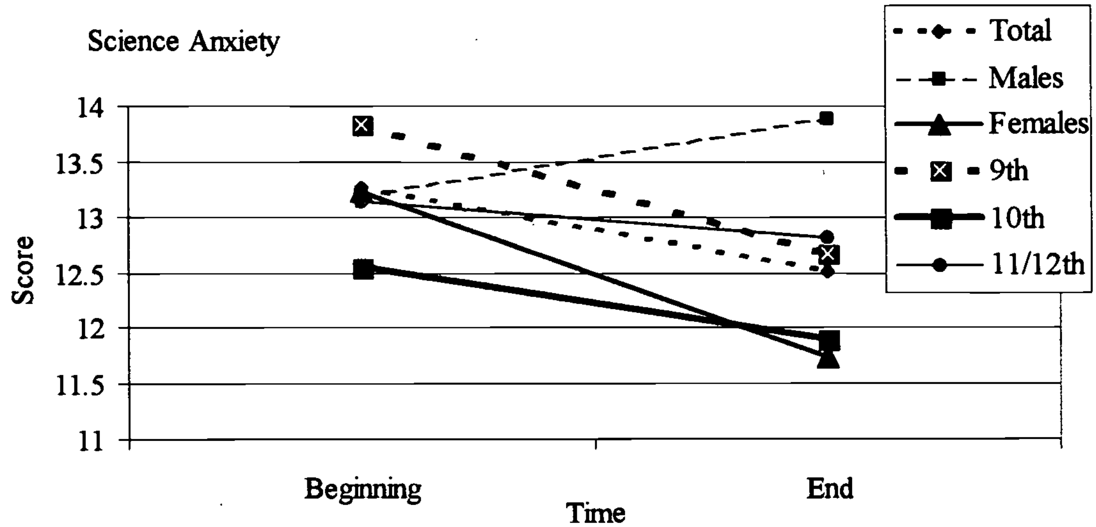

Figure 4. Change in levels of student anxiety toward science by group over time. The maximum score was 20 and the minimum was 4.

No significant differences were found when comparing the gender groups at either time of the administration, except at the end when females had a significantly lower score in Science Anxiety ($p<.011$), meaning that females had more anxiety.

Conclusion

The results from several parts of this instrument replicate findings from its first usage 20 years ago. First, the reliability values found indicate that the Simpson-Troost instrument is still useful in providing a glimpse into students' collective views on several important variables of interest to researchers in the school experience. Although two items used on the instrument decreased the reliability of subscales, the use of this instrument to investigate the principle subscale (Attitude Toward Science) demonstrated

reliability. Almost all alpha values reported in this administration were similar to those found by Talton and Simpson (1986) in their analysis from data twenty years previous. The two items on the instrument that decreased the reliability in their respective subscales may need to be examined in future uses where these subscales are a primary part of the investigation.

With the reliability of the instrument supported, the research questions posed become important. Previous research showed significant relationships between students' attitude toward science and other classroom environmental variables. This study used subscales of Emotional Climate of the Classroom, Attitude Toward the Science Teacher, and Attitude Toward the Science Curriculum to investigate these previous claims. The Pearson correlation coefficients that were found from this population further support the relationship between classroom variables and a student's attitude toward science. The coefficients found with this group show either moderate or modest positive relationships between all subscales. This lends support to the idea of this study that changing the structure of the classroom may have some effect on improving attitudes toward science in the classroom. Although this is far from being the only factor influencing these attitudes, the research shows support that the environment plays an important role in how students feel about science.

Differences between grade levels and gender were also found in this study. One of the most glaring differences found in the data are the large declines in Grade 9 on most subscales. Although the only significant change ($p<.05$) was in the Emotional Climate of the Classroom, two other variables dropped quite dramatically, and with a larger sample

size, may have showed significance. Science Anxiety (Figure 4) and Attitude Toward the Science Teacher (Figure 5) each dropped with a significance of approximately 0.10.

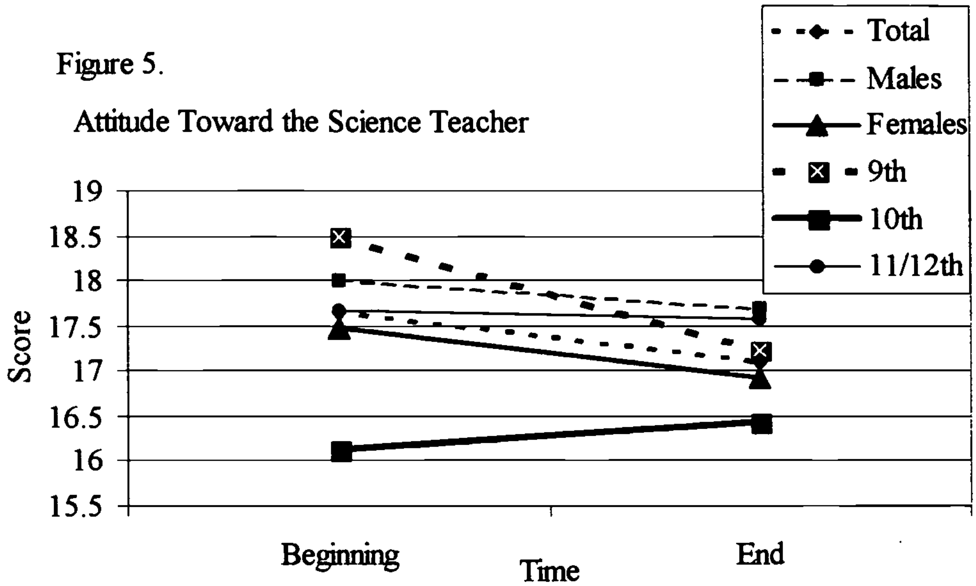

Figure 5. Change in levels of students' attitude toward the science teacher. The maximum score was 25 and the minimum was 5.

More puzzling was that, although many of these subscales dropped quite a bit, the Grade 9 students' Attitude Toward Science actually increased. The t-value that was associated most closely with this subscale was in the students' Science Self-Concept.

Some of these finding have been reported in previous research. For instance, Simpson and Oliver (1985) presented data that showed Grade 9 students reported higher attitudes toward science than Grade 10 students. Possible explanations for this may be found in the novelty and excitement of being in a new school after leaving the middle school years. However, students may quickly come to dislike their science classes, and other classes, as well, because of the high academic demands that are placed upon them as they enter high school. With state mandated achievement tests influencing the amount

of fact acquisition by students in this study, it is not surprising to find that they come to dislike certain aspects of school as the year passes.

Another interesting observation of the data was the increase found in Grade 10 students on four of the six subscales. These students also began the year with lower scores on all scales. This is a phenomenon that seems anomalous when comparing the data to previous research. One possibility is that many of these students developed negative feelings about high school during their first year and became more acclimated as their second year continued. Students in Grades 11 and 12 showed the most stable results of all grade levels, suggesting the possibility that attitudes in the science courses may become more difficult to change as the students continue through their school experience.

There was little significance found in comparing males and females, but the fact that males reported more positive scores than females on all subscales is worth noting. With the widespread research into gender differences in science and in science careers, this study gives further evidence to these differences. Even though the females' score on Attitude Toward Science decreased, it was not significant. The only subscale in which female scores did not decrease was in the Attitude Toward Curriculum. This is the subscale that most directly relates to what is occurring in the science classroom. Although the classroom experiences of females in this study led them to report decreases in all other scales, an increase was found in how they felt about the science class itself. Perhaps the extended block of time is more in line with how females like to learn in the science class, with the very small decrease in Attitude Toward Science lending support to this.

Limitations and Implications

This study does not allow for generalizability to all other school groups. The population used for this study is very different from those found in many parts of the United States. However, there are many schools in the rural Southeastern United States that have characteristics very similar to this one. The low scores reported at the beginning of the semester by these students in comparison with the data reported from the early 1980's is of particular concern. Although there was little change in students' attitude toward science throughout the semester, the fact that these poor, rural students of color (80%) were much more negative toward science may suggest a future of science that continues to lack members from such a background. Research into the learning experiences of these students in their early years could help discern reasons behind this.

The influence of high stakes testing is also of concern in this study. Although not mentioned before, this school had scored in the lowest 25% of all high schools in several sections of the state mandated high school graduation exam, which must be passed in order for students to earn a diploma. Because of this, quite a bit of classroom time is dedicated to reviewing topics that are a part of these tests. Although such tests are well-intentioned in their goals of producing more knowledgeable students, they may do so at the expense of student attitudes toward science and learning. These tests may have an influence in the large decline in Science Self-Concept found in this sample of students.

One of the main limitations of this study was in the lack of data supporting how the classroom environment actually changes when a block schedule is implemented. Although there is support that teachers working during a 90 minute block of time make the classroom more centered on the student, empirical evidence for this is minimal at best. Future studies comparing teaching methods and planning by teachers using the

block schedule with those on a traditional schedule would help in identifying whether or not these are advantages that are actually occurring in the classroom. Although I feel confident, through colleague conversations and informal classroom observation, that the classrooms used in this study were student-centered, hard evidence would better support the idea that the 90 minute block schedule creates a learning environment that is more conducive to positive student attitudes.

Even though the scores reported by these students in their attitude toward science were lower than data previously found, the fact that there was little decline during the course of the year is an important finding in support of implementing the 90-minute block schedule. For whatever reason, though not pinpointed in this study, student attitudes were only minimally lower at the end (and higher in some groups) than at the beginning. Also important to note was the increase by all groups in their Attitude Toward the Science Curriculum (Figure 6).

Figure 6.

Attitude Toward Curriculum

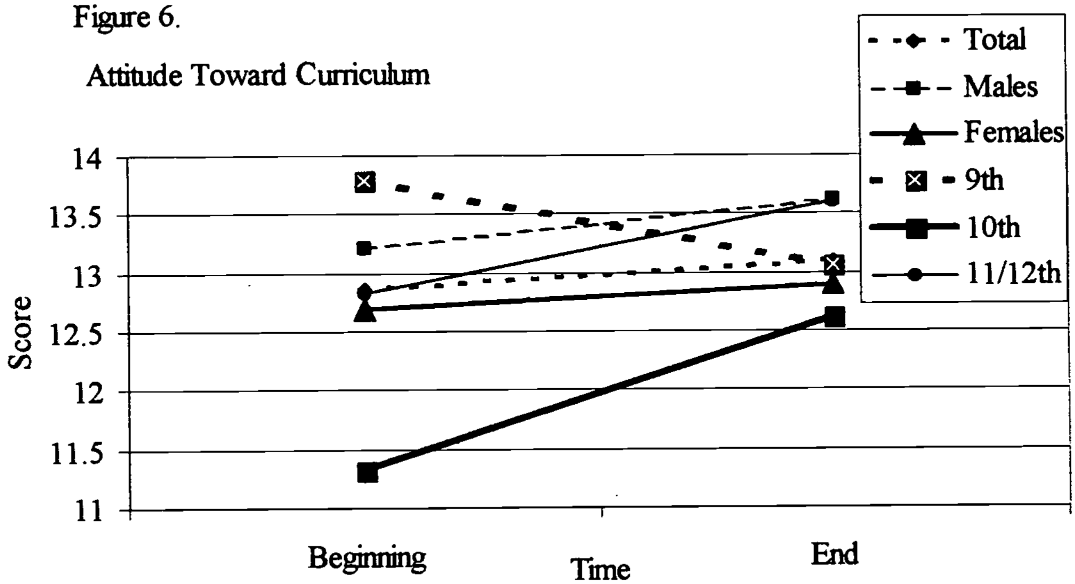

Figure 6. Change in the students' attitude toward the science curriculum. The maximum score was 20 and the minimum was 4.

In particular, female students reported the most positive changes in this category, providing support that this type of scheduling is consistent with their learning styles and preferences. Further research into this may prove fruitful.

Although attitudes toward science are not an area of bountiful research in recent years, these topics are still important to look at when large-scale changes are made at the school level. If we can implement changes into the science classroom that have a positive effect on affective dimensions of learning, this may be as important a transformation in students as in their cognitive gains. The continued concerns of future pursuit of science as a career is connected, as shown above, with how students feel about science. Providing an environment that can foster these feelings without sacrificing achievement should be a goal of the science education community, especially if minority growth in the sciences is of concern.

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A REVISED INTRODUCTORY-LEVEL COLLEGE SCIENCE COURSE: STEPS TOWARD AN INCLUSIVE PEDAGOGY

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If we are to improve the interest, achievement, and participation of females in math and science, focus must be on how students are being taught and acquiring knowledge. As discussion increases surrounding this issue, and the mediocrity of science and math education in the United States (Tobias, 1992), many higher education institutions and individual professors are revising their programs (Stewart & Osborn, 1998; Roychoudhury, Tippins, & Nichols, 1995; Chambers & Andre, 1997; Mayberry & Rees, 1996). Improvements, enhancements, and all-out revisions at the college level are necessary. Instructors of introductory college-level science courses can potentially advance or neutralize female science interest and learning. The "discourse of gender neutrality" (Eisenhart & Finkel, 1998) as it relates to assumptions about reform efforts may, however, mask the realities of female experience in revised courses. Course structure and a professor's pedagogy need study and description to understand how to provide females access to practical and theoretical knowledge that offer pathways (Davis, 1999) into the science community.

Context and Purpose of the Study

In 1996, the National Science Foundation (NSF) awarded a Collaboratives for Excellence in Teacher Preparation (CETP) grant to a large Massachusetts State University and surrounding private and community colleges. Over one hundred professors joined the Science, Technology, Engineering, Math, Teacher Education Collaborative (STEMTEC) project with the hope of utilizing greater student-active learning strategies in their teaching. A portion of the STEMTEC grant's abstract describes its intention:

> A major component of STEMTEC will be the support of discipline-based curriculum teams which will develop new and revised college science and math courses. In addition to college faculty, these teams will include K12 teachers and education professors who are experts in the new pedagogy. Because most teachers teach the way they were taught (Shymansky, Hedges, and Woodworth, 1990), these courses will model the most effective teaching strategies and tools: cooperative learning, investigation-based teaching, educational technology, new assessment techniques, and opportunities to teach (NCTM, 1991; NRC, 1996; AAAS, 1993). Since the best way to understand the nature of science is to actually do real science, we will offer all undergraduates the opportunity to conduct original research. STEMTEC will use these established teaching strategies to reform the way we teach science and mathematics to future teachers. (Stemtec Proposal, 1995)

The original STEMTEC proposal identified several needs related to science education. The study described in this paper specifically addresses Need #3:

> Many minority groups continue to be under-represented in science and mathematics education (Oakes, 1990). Nationally, 30% of the students belong to under-represented minority groups, but less than 10% of the science and math teachers are from these groups. (Weiss et al., 1994; NCES, 1994). Over the past 20 years the number of women teaching secondary mathematics has increased to approximately half the total, but only a third of the high school science teachers are women. The Massachusetts statistics are similar to the national data (MA Dept. of Ed., 1996). We need to recruit and retain women and minority students in the appropriate college majors and into teaching.

The focus of this study is to explore the initial part of Need #3 by considering the impact of pedagogical and course revisions on female interest and perceived learning in a STEMTEC introductory level science course. The study offers links between inclusive and reformed science education pedagogy and elucidates their necessary (and innate) coexistence in reform efforts. As an exploratory study, it seeks to raise awareness regarding the possibility of effective inclusive college-level science course reform. The questions guiding the study are; How does a professor's reformed pedagogy impact female interest and learning in science? Where and how do important elements of inclusive pedagogy, namely, classroom power, relevance, and discourse, emerge in the reform effort?

A Feminine Perspective: The Call For A New Pedagogy

Burbules (1989) separates the type of educational questions feminists research into two areas. The first area relates to the content learned in schools (i.e. is it inclusive with respect to the contributions and participation of women?) and the second focuses on feminine perspectives and ways of thinking (i.e. are there female ways of solving problems and making choices that have been traditionally ignored and denigrated?). Roychoudhury, Tippins, & Nichols (1995) expound on this second area. They describe the epistemology of feminist standpoint theory as the relevant theory through which reformists of science education can envision change.

Feminist standpoint theory propounds that knowledge generation is not gender-free. Instead, because knowledge is created socially, and the life experiences of females and males differ, gender differences exist with respect to knowledge generation. Females and males, therefore, have different ways of understanding and problem-solving within the shared experiences of life and learning. Science has developed and operates within a white male-dominated realm of experience. It is propounded to be objective, logical, and unemotional. Women's perspectives on science learning and problem-solving differ in their approach, goals, and progression and thus offer an enhanced methodology to this view of science (Keller, 1985). Female ways of knowing bring knowledge generation into a more holistic, personal, and issue-based realm. Without these perspectives in science, women continue to feel uninterested and negative toward the discipline. Without these perspectives in science, women continue to opt out (Seymour & Hewitt, 1997).

Feminist perspectives of a female worldview demand consideration in science education and women's everyday lives (Harding, 1991). A female worldview (Tobias, 1982; Belenky, Clinchy, Goldberger, & Tarule, 1986) determines how a student observes and makes sense of her physical and natural world. Understanding how females construct knowledge and how to make

that knowledge relevant is a first step toward an pedagogy aimed at the inclusion of girls in science and math (Cobern, 1990).

What does an inclusive science teaching pedagogy look like? Roychoudhury, et al (1995) make a strong case for the connection of women's everyday experiences with the science they are learning. This is more than discussing "kitchen chemistry" in that it calls for a reformed way of teaching and creating learning atmospheres that allow females to think and express themselves safely. Such an environment must shed its traditional power structure, allow for and promote meaningful reflective sharing in many forms, and explicitly relate curriculum to the everyday lives of the students. The characteristics of this pedagogy will therefore be defined under the major themes of classroom power, discourse and relevancy. These themes are described further in the sections below.

Classroom power

Drawing heavily on the work of critical theorist Paulo Freire (1983), hooks (1994) describes her role as an educator. She admonishes the teacher who "doesn't care", and strongly urges pedagogic practice that exhibits care, interest, and concern for the individual student. She asserts that the interaction between student and teacher is critical to the student's learning, sense of belonging, and ultimately motivation to learn. This requires an elimination of the power role of teacher as unemotional authority figure and promotes teacher as mentor.

Hildebrand (1998) offers the concept of an enabling pedagogy, which draws on aspects of feminist, critical and hegemonic pedagogies. An enabling pedagogy works to balance the play of power in the classroom by realizing the inherent and necessary authority of the teacher yet promotes an broad program that effectively considers the affective, cognitive and sociocultural contexts of the teacher and students. In such a setting, students work with teachers to determine

learning needs, relevant topics of study, and assessment strategies (Roychoudhury, 1995; Mayberry & Rees, 1997). Decision-making is shared within the available context of the setting.

Inclusive pedagogy requires such considerations to be made. Balancing classroom power is integral to an effective inclusive pedagogy. In power balanced settings, teachers see themselves as true advocates of student learning and are available mentors. They not only exhibit explicit care, interest, and concern for their students well-being, they believe that each student has important valid contributions to make to the class discourse and act on that belief through curricular decisions. Besides bringing this human-element into the classroom, teachers who strive to balance power understand the history and nature of their science in such a way that it impacts how they teach their subject. They see their students not as passive recipients of scientific truth, but active learners who can and should understand the changing nature of scientific methodology and theory. As a result, they give students voice concerning what is taught, how learning occurs and who can generate scientific knowledge.

Relevancy

An inclusive pedagogy promotes the need for the "everydayness" of science to be made accessible to students. Lemke (1990) believes that all students should understand science well enough to use it effectively in their daily lives. Traditional science-as-usual (Harding, 1991) education does not, however, makes scientific knowledge and thinking available to students because it promotes harmful myths of science that "favor the interest of a small elite" (Lemke, 1990, p. 129). As a result, science is often taught out of context, devoid of history or social implications, and has little impact on most students' personal and professional lives. Also, because science is taught through complex spoken and unspoken communications that portray its supposed extreme difficulty and specialty, science seems unattainable to the majority of students.

Roychoudhury et al. (1995) promote science teaching that is relevant to the lived experiences of females and meets personal needs. For an inclusive pedagogy, this means placing scientific theories and concepts in their historical and social context and examining their contemporary impact at the personal and global level. It also means that teachers must know who their students are with respect to their interests, needs, and chosen career paths in order to guide learning and choose content material effectively. Practical strategies to promote relevancy include using student-selected long-term projects (allowing for the personal bonding of student interest with project issues), incorporating cooperative work groups and allowing students to negotiate and choose assignments for assessment of their learning.

<u>Discourse</u>

Ball (1993) writes that "Discourses are about what can be said, and thought, but also about who can speak, when, where and with what authority" (p. 14). Lewis & Simon (1986) analyzed the gender discourse within a college classroom. They conclude that, in order to counter a "patriarchic practice", a struggle must be waged between academic (supposedly) objective discourse, and the articulation of our everyday experiences. The adherence to that struggle manifests itself when teachers "create a space for the mutual engagement of lived difference that is not framed in oppositional terms requiring the silencing of a multiplicity of voices by a single dominant discourse"(p.469). Lemke (1990) offers a multitude of instructional and philosophical reforms that make explicit the mystique of the dominant science discourse and allow students the opportunity to practice the everyday as well as "expert" language of science. The idea of making explicit the nature of science and dominant discourse opens the door for "other" voices to be heard.

A strong advocate of the female voice, Gilligan (1990) divulges the sublimated world in which girls' true questions and thoughts exist. She considers what it means for women to be

teachers of girls and how to recreate the teaching agenda and classroom discourse. She asks, "Whose agenda, what is important, what can be spoken and what is tacitly to be ignored - looked at but not seen, heard but not listened to? (p. 503)." Urging the creation of a new order for teaching practice, she promotes a pedagogy that is permissive in its discourse and allows girls to be honest and true in their public displays of knowledge and inquiry.

The consideration of discourse in an inclusive pedagogy calls for classroom atmospheres that utilize discourse as a means to uncover the mystique of science and transcend its traditional modes of information transfer, language, and discussion. Through equitable inviting discourse a balance of power can be realized and true relevancy achieved. This can be accomplished when, for example, students interact in groups that are mindful of dominance and isolation and teachers speak as a mentors in support of learning rather than bearers of scientific truth. A philosophical and practical implication of this is Hildenbrand's (1998) hybrid imaginative writing. "Hybrid imaginative writing includes any blended genres that use scientific and/or factual genres (recounts, procedures, reports, explanations, expositions, discussions, etc.) in conjunction with imaginative or fictional genres"(p. 347).

A Framework of Inclusive Pedagogy Themes

Determining the themes of classroom power, relevancy, and discourse as central to an inclusive pedagogy lead to the creation of a framework of their respective elements (Table 1). This framework is a document in progress. Using the framework as a guide, a pilot study was conducted in a revised introductory-level college science course to illuminate the requisite changes and accomplishments of the effort in light of an inclusive pedagogy.

Table 1

Elements of an Inclusive Pedagogy for Science

Attempts to balance *Classroom Power* (Within learning environment)	Strives for *Relevancy* (Curricular issues)	Focuses on *Discourse* (Types of and strategies to promote discourse)
Non-competitive learning environment	Links to everyday life and careers	Frequent discussion/assessments
Supportive & caring learning environment: non-threatening, meaningful interactions between teacher-student & student-student	Increased focus on social causes and problem-solving scenarios from traditionally female dominated fields	Use of cooperative learning groups
Overt teacher interest in student knowledge and ideas	Opportunities to hypothesize about the effect of gender on curriculum choices and to understand the global/holistic issues and impacts of a particular topic or activity	Accessing, considering, and using students' prior conceptions
Open-ended curriculum with respect to content/direction & student interest/need	Opportunities for personal bonding with projects (use of long-term)	Practice in the expert and everyday language of science
Explicitness of "science-as-usual" phenomena and its impact on marginalized communities	Portrayal of female scientists and leaders in resource materials	Permissive in its promotion of the female voice (opportunities to state ideas & opinions and practice asserting knowledge)
Explicit invitation into field of study as a profession	Use of variety of resources from differing perspectives	Opportunities to share learned content through imaginative writing & use of metaphors
Variety of assessment strategies utilized: peer/oral/portfolio/ performance-based assessments	Manipulations with common materials (and use for data collection/problem solving activities)	Use of multi-media for learning and representing student work

(table continued)

Table 1 (continued)

	Utilization of interesting, important and colorful objects/posters around classroom	Make explicit the dominant discourse of science
	Field trips/outings/use of alternative learning environments	Promotes student reflection and elucidation of ideas/questions
	Career information and academic counseling	

Table 2 was created by T. Weiss (2000) from the writings of Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M., 1986; Davis, K. S., 1999; Davis, K. S., 2000; Gilligan, C., 1990; Kahle, J.B. & Meece, J., 1994; Harding, S., 1991; Hildebrand, G. M., 1998; hooks, b., 1994; Lemke, J. L., 1990; Lewis, M. & Simon, R. I., 1986; Oakes, J., 1990; Rosser, S.V., 1990; Rosser, S.V. & Kelly, B., 1994; Roychoudhury, A., Tippins, D. J., & Nichols, S. E., 1995; Sadker, M., Sadker, D., & Klein, S., 1991; Stewart, G. & Osborn, J., 1998; Tobias, S., 1992; and Woodhall, A. M., Lowery, N., & Henifen, M. S., 1985.

Project Setting

The students participating in this project were enrolled in a revised introductory level science course at a large state university in Massachusetts. The students are approximately 91% white, 3% Hispanic, 2% African-American, and 2% other ethnicities. In the class of 615 students, 387 are female and 228 are male. Academic year for all respondents ranged from freshman to graduate students. Approximately 90% of the students are majoring in fields other than science, math, or engineering. Two sections of 300+ students meet twice/week for 1 hour and 15 minutes. One professor and 2 teaching assistants conduct the course.

STEMTEC revisions to the course included (a) paring down the lecture from the whole period to 45 minutes, (b) adding a 30 minute cooperative group work exercise out of a professor authored workbook, (c) adopting the 2-stage exam structure whereby students take the exam solely first, then with a cooperative group, and (d) implementing an on-line immediate feedback homework program (OWL – On-line Web-based Learning).

Method

The study included both quantitative and qualitative data collection and analysis methodologies. The primary sources of data collection consisted of analysis of student surveys, professor and students interviews and classroom observations (Table 2) using a data analysis method of grounded theory, consisting of constant comparison analysis and triangulation (Cronin-Jones, 1991; Glaser & Strauss, 1967). Data was examined for regularities, patterns and assertions (statements describing patterns). Specific course characteristics were accepted as evidence of inclusive pedagogy if the language used and/or meaning intended by the respondents could be clearly linked with its major themes and elements.

Table 2
Data Sources

Data Source	Description
CETP End-of-the-Semester Course Survey (Fall 1998)	This STEMTEC grant-produced survey was from the same course, offered the previous year, under a different but major collaborating professor. Survey analysis was conducted on one lecture class of 368 students (232 females and 136 males). Results from 6 questions covering topics such as class participation/involvement, encouragement, metacognition, science interest, and science ability were utilized.

(table continued)

Table 2 (continued)

Classroom Observations	Open narrative observations of the class were conducted 4 times. Attempts were made to record professor student-interactions and behaviors throughout the periods.
Female Impressions Survey	The Female Impressions Survey was collected from 126 females to understand their impressions of the course and professor in a general sense. The survey was composed of 4 questions. Questions 1-3, in Likkert Scale format, asked about the professor's ability to motivate learning, amount of learning taking place, and any changes in interest in science as a result of the course. Question 4 was an open response type question in which respondents could comment on any aspect of the course that promoted or impeded learning.
CETP End-of-the-Semester Course Survey (Fall 1999)	This survey was created and disseminated by the STEMTEC grant. Analysis was conducted on responses from 164 students (115 females and 49 males). Results from 4 questions covering topics such as class participation/involvement, encouragement, metacognition, and science interest informed this study.
Professor Interviews	Two interviews, one formal one informal were conducted during the course. The professor was asked to describe his personal science/teaching history, teaching philosophy, involvement with the STEMTEC grant, and course changes/goals for students.
Student Interviews	Nine semi-structured female student interviews were conducted. The student interviewees were volunteers. Email follow-up questions were sent to all nine females.

The framework for data analysis was derived from a synopsis of inclusive pedagogical themes evident in the literature (Cobern, Ellington, & Schores, 1990; Frazier-Kouassi, 1990; Gilligan, 1990; hooks, 1994; Kahle & Meece, 1994; Harding, 1991; Hildebrand, 1998; Lemke, 1990; Lewis & Simon, 1986; Oakes, 1990; Rosser, 1990). Major themes were determined to be (a) classroom power, (b) relevancy, and (c) discourse. Coding data with respect to the major themes assisted in describing those practices and classroom structures that are reported to be inclusive to females.

Results

Surveys

CETP Survey (Fall 1998)

Data analysis from the previous year's CETP project end-of-the semester student survey (Fall 1998) revealed that 86% of the females and 84% of the males agreed that the teaching methods of the revised course helped them learn. Yet, notable differences occurred between females and males in survey questions regarding class participation, asking questions, metacognition, science interest, and abilities necessary to understand science. Table 3 offers the notable response differences between females and males to specific survey questions. This window into gender differences existing in a STEMTEC course made a strong case for the need to critically consider the assumption that reform benefits all equally.

Table 3
Gender Analysis of End-of-Semester Survey Questions for Introductory Level Science Course (Fall 1998 – one year prior to study)

End-of-Semester Survey Questions Fall 1998	Females	Males
Encouraged to think about own learning (percent in agreement)	38%	49%
Never or rarely participated in class discussion (percent in agreement)	63%	44%
Never or rarely felt encouraged to ask questions (percent in agreement)	34%	16%
Looking forward to taking more science classes (percent in agreement)	22%	35%
Understanding science requires special abilities (percent in agreement)	17%	31%
Course increased interest in subject (percent in disagreement)	20%	12%

Female Impressions Survey

To begin describing female experience in the revised STEMTEC course, the study commenced in the Fall of 1999, beginning with the Female Impressions Survey. The goal of this survey was to offer females an opportunity to describe their impressions of the course and professor. One hundred and twenty-six females responded. Results of the 4 question survey indicate that the majority of females (72%) feel that the way the professor teaches motivates them to learn and over half (59%) felt that they had learned more in this course than in other science courses. A third question asked whether or not the course had increased their interest in science. That result was split in thirds between agree, not sure, and disagree. Question 4 asked students to write about characteristics of the course/professor that promoted or impeded their learning. Table 4 presents the percentage of grouped responses to Question 4. Two important results of Question 4 are the high percentage of females (approximately half) stating that the professor's teaching ability and the use of collaborative groups promoted learning (note: 20% of the respondents did not complete Question 4).

Table 4
Female Impressions Survey Question 4 Responses

Impedes or Promotes Females Learning and/or Interest in Science	Promotes	Impedes
Professor as a teacher/lecturer	48%	7%
Power-Point presentations during lecture	9%	3%
Course Relevancy	2%	10%
(impact on major, daily life, career)		

(table continued)

Table 4 (continued)

Pyramid Exams/Workbook & Collaborative Groups	51%	5%
OWL Assignments (on-line homework tutorials), Review Sheets, Textbook, Videos	13%	4%
Course Organization & Grading	7%	
Films, labs, field trips, class discussion, TAs, lecture hall, class		15%

CETP Survey (Fall 1999)

A second survey was utilized in the Fall 1999 study of this course. Data analysis from the CETP project's end-of-the semester student survey (Fall 1999) revealed a fairly gender equitable impression of the course. Overall, half of the females and males agreed that they participated in class and the course increased their science interest. A higher percentage of females than males reported feeling encouraged to ask questions in class. A higher percentage of males than females reported that they felt encouraged to think about their own learning. Table 5 presents these findings.

Table 5
Gender Analysis of End-of-Semester Survey Questions for Introductory Level Science Course (Fall 1999)

End-of-Semester Survey Questions Fall 1999	Females	Males
Encouraged to think about my own learning (percent in agreement)	19%	42%
Participated in class discussions in almost every or every class (percent in agreement)	74%	70%
Felt encouraged to ask questions in almost every or every class (percent in agreement)	47%	28%
Course increased interest in subject (percent in agreement)	71%	72%

Professor Interview

The professor of the Fall 1999 course is a very motivated teacher. Informal discussions and a formal interview indicate his strong commitment to effective teaching. During our interview he stated, *"My teaching is my research. Others think I spend too much time on this, but I know it's important."* His history of interest in teaching stems back to his days as an undergraduate experiencing poorly taught sciences courses. He cites the CETP project as a major factor in his ability to change in his teaching and course. The professor is well aware of the challenges facing effective teaching in a large lecture setting. He raises questions about the quality of students' learning as they work in cooperative groups and the amount of content students are expected to learn. More specifically he is aware that he lectures too quickly and worries that students are frustrated with on-line accessibility problems with the homework assignments.

As the father of a daughter, the professor states he is keenly interested in issues of female learning in science. Course changes, however, were made with the goal of improving science-for-all without critical considerations into the "science-as-usual" hidden and hegemonic practices inherent in the course (note: The STEMTEC grant, at the time of this study, had not critically and reflectively addressed such nature of science issues in its workshops and seminars geared toward course reform). In general, the professor summed up his goal for his students in this way; *"I want all my students to understand how the Earth works, the big picture. They need to be able to use science in their everyday lives."* This statement aligns him with, according to Roscoe, Chun, Kemp, Jackson, Li, Oliver, & Tippens (1999), most educators', scientists', administrators', parents', and other community members' general definition of scientific literacy,

that is “a set of knowledge and/or skills which are essential to function in a literate fashion in our society” (p. 1).

Classroom Observations

Four observations of the class were conducted. An excerpt from one observation sets the tone for how the class begins:

> The professor is ready for students about 10 minutes before class begins. Five to ten students seem to crowd him before each class. Students are asking questions on specific course issues and general content information. The professor and students are smiling and laughing during these informal discussions.

During the class, a structured protocol exists in which a 45-minute computerized lecture presentation is followed by cooperative group work. The professor asks students between 7-10 questions during the lecture. Students ask, on average, 1-2 questions during this time. Over half of the professor-directed questions are simple recall, such as, “Who are the grazers on the land?” and “Has anyone ever been to Cape Cod?” The remaining few questions delve into the competencies of students’ knowledge comprehension and application, for example, “What strikes you about the distribution of chlorophyll in this image?” Females answered and asked questions during class twice as often as males. During one observation, 8 of 10 lecture interactions were between the professor and female students.

Throughout the lecture students follow along out of their workbooks and take notes along the sides of the diagrams and text. During the last 30 minutes of the class, students work in cooperative groups to solve problems from numbered workbook activities. Workbook activities vary from numerical calculation, prediction, and analysis to free-writes about specific terms/concepts. Workbook sheets are turned in to the teaching assistants at the end of class for a satisfactory or unsatisfactory grade. Students cannot make-up missed workbook activities.

A number of elements of inclusive pedagogy were observed during the classroom observations. The elements observed and evidences supporting them are presented in Table 6.

Table 6
Elements of Inclusive Pedagogy observed during introductory-level science course

Elements of Inclusive Pedagogy / Observation	1	2	3	4
Overt teacher interest in student knowledge and ideas	X	X	X	X
Permissive of female voice	X	X	X	X
Supportive caring and learning environment	X	X	X	X
Non-competitive learning environment	X	X	X	X
Frequent discussion/assessments	X	X	X	X
Use of cooperative learning groups	X	X	X	X
Links to everyday life:	X	X	X	X
Use of multi-media for learning		X	X	X
Use of a variety of resources	X	X	X	X
Utilization of interesting, important and attractive objects		X	X	X
Practice in the expert and everyday language of science	X	X	X	X
Inclusion of females in content resources		X		

Student Interviews

Nine female students volunteered to be interviewed about their impressions of the course and the professor. The make-up of the interview group consisted of 3 sophomores (majors: psychology, communication/elementary education), 5 juniors (majors: business, French, sociology/elementary education, geology), and 1 senior (major: hotel restaurant management). A semi-structured interview protocol was used. Interview questions served as a guide for

discussion and time was given for students to describe other pertinent information. One interview was conducted with each student for approximately 45 minutes. Interviews were hand-recorded as they commenced and notes were rewritten following each session. All students were emailed follow-up questions to which 8/9 replied via email. Categories of responses chosen from emerging patterns in the dialogue and are presented in Table 7.

Table 7
Interview Response Categories from Focused Student Interview

Interview Response Categories/ Student Major & Year	Fr. Jr.	Bs Jr.	Bs Jr.	ScE Jr.	Ps So	Ps So.	CoE So.	HR Sr.	ES Jr.
Dislikes physical science	X	X		X	X		X	X	
Professor makes science accessible	X	X	X	X	X	X		X	
Trouble with math		X	X		X	X	X	X	
Cooperative groups very useful	X	X	X	X	X	X	X	X	
Increase class discussion	X	X	X	X		X		X	X
Learning from course in form of discrete bits of concepts/facts	X	X			X	X	X	X	X
Course beneficial because it's easy		X	X			X		X	
Course beneficial because it's interesting		X		X	X	X	X		X
Course not beneficial	X							X	X
Wants more in-depth learning of topics		X							X
Course is relevant			X	X					

Note: Fr. = French, Bs = Business, Sc = Sociology, PS = Psychology, Co = Communications, E = Elementary Education, HR = Hotel Restaurant Management, ES = Earth Science, Jr. = junior, So = sophomore, Sr. = senior

Discussion

The previous year's gender disparities in the responses to the CETP end-of-the-semester survey questions (Fall 1998) warranted a closer look at the course and its ability to include females in the enterprise of science. The Fall 1999 CETP end-of-the-semester survey data reveals that this course did increase female impressions of their involvement. (Nonetheless, the majority of females do not agree that the course gives them opportunities for metacognition.) In general, triangulation of the data reveals that the professor's reform efforts are increasing female interest and participation in the science of his course. Many of these efforts correspond directly with elements of inclusive pedagogy, which may explain female support for the course. In this section, the major themes of inclusive pedagogy, namely, classroom power, relevancy, and a focus on discourse are illustrated specifically within the context of the data sources.

Major Theme of Inclusive Pedagogy: Balances Classroom Power

In considering the theme of classroom power, data was sought reflecting the theme's 7 elements; (a) issues of equity and caring (hooks, 1994) within the learning environment (collaborative group work, (b) open and reflective classroom discourse), (c) explicitness of the "science-as-usual" phenomena (Harding, 1991), (d) the "open-endedness" of the syllabus and class focus (Roychoudhury, et al., 1995), (e) use of alternative assessment strategies, (f) use of imaginative/reflective writing (Hildebrand, 1998), and (g) opportunities for individual reflection time with teacher interaction. Many examples of an attempt to balance classroom power were found. There were also strong indications of a teacher-driven course lacking student input.

The data collected reveals a professor making important attempts to balance classroom power in his course by how he thinks and acts. This effort can be described in three ways. First, as evidenced by how he thinks. As student groups began to form for the cooperative part of the 2-stage exam, the professor said, *"Watch this, it gets to be chaos in here, but it's great, they're*

really talking." This comment discloses his support for allowing students control over and share in their learning. He also stated that he believed the group work helped students feel good about turning in their work. His impressions are that because the students felt more confident in their answers after cooperative group work, they were more secure and comfortable with their knowledge. Secondly, the professor creates an equitable and caring learning environment during class. Observations and student comments reveal him to be highly enthusiastic, interested in students and their ideas, and invested in student learning. He portrays elements of teacher-as-coach through his use of summary, paraphrasing, analogy and metaphor and attempts to continually check for student understanding. The professor was observed actively engaging with as many groups as possible during the cooperative group work portion of the class. Finally, these efforts make him very approachable in the eyes of female students and create a non-threatening learning environment. For example, at the beginning of each class observed, 5-8 females were waiting to ask questions of the professor and over 50% of professor-student interaction during lecture included females. The use of cooperative groups for workbook exercises and exams aid in female impressions of a non-threatening learning environment. His use of raw data and satellite imagery in the computerized lecture presentations combined with how he draws the students into thinking about what slides also supports this claim. Classroom observation data offer examples of how the professor treats his students almost as colleagues as they together make sense of scientific phenomena. For example, in a moving diagram of longshore drift, he replays the image over and over, asking students to explain what they are seeing and why it is happening. He also asks hypothetical questions about the image to expose students to scientific thinking, such as, "I wonder if this happens the same in all seasons? Along

all beaches around North America?" Excerpts from student surveys and interviews reflect females comfort level with his personality and teaching style.

> He (the professor) has really gotten me interested in the science by piquing my interest and making science more accessible.
>
> The Professor's teaching style is very comfortable and non-threatening.
>
> His enthusiasm is contagious, it makes me want to learn.

The four lectures observed, however, were also mostly pedantic. Students followed the presentation in their workbooks, highlighting information, taking additional notes, or reading along with the professor. The organization of the syllabus was non-negotiable as was the material covered in the lecture itself. Outside of the opportunity for students to ask questions during lecture or informally with the professor, no mechanism appears to exist for students to explore their own interests within the framework of the course. Teacher-student interaction during lecture made up approximately 15% of class time. A small number of students were able to verbalize their frustration with this aspect of the course.

> I find certain things interesting but all too often they are only a piece of the main issue and not a focus.
>
> It gets slow and boring watching the screen with pictures and just listening along.
>
> Lectures are repetitive and boring as they say exactly what is written in the book.

Course revisions must address the following areas to continue to disrupt its teacher-driven transmission-type curriculum and further enhance its accomplishments in balancing classroom power. Recommendations are for course revisions to address the need for student-directed learning opportunities through syllabus open-endedness, explicitness of the "science-as-

usual" phenomena, use of imaginative/reflective writing, and opportunities for individual reflection time (discussed more in the next section). To address these issues, course revision should focus on (a) accepting flexibility with established content material and (b) increasing opportunities for student reflection. More specifically, the professors need to pare down course content and allow for student-directed topics to be investigated through lecture, group work, and alternative assessment strategies (such as presentations, free writing, and long-term projects). Course content needs to better reflect the history of the science as well as the social nature of knowledge generation and scientific paradigms (Lemke, 1990). Also, mechanisms increasing individual student reflection through writing, drawing, constructing hypotheses and teacher-student interaction require consideration. Identification of students' conceptions and misconceptions prior to new topic introduction and increased use of higher order questions during lecture need to occur with more frequency and quality. These suggestions give females greater opportunities to engage actively in their learning and open doors to positively addressing issues of "female voice".

Major Theme of Inclusive Pedagogy: Focus on Discourse

The course makes a very strong attempt to focus on discourse for all students and, as a result, benefits females. The data collected during the student/professor interviews, classroom observations, Female Impressions Survey, and the CETP end-of-the-semester survey (1999) support the claim that the course exemplifies three important elements focusing on discourse (see Table 2); (a) permissive in its promotion of the female voice, and (b) use of cooperative learning groups and (c) practice in the expert and everyday language of science. Females' level of participation during lecture and informal discussions with the professor as well as their support for cooperative group work support this claim. One female reported that the way the professor

spoke positively impacted her. The following quote offers a glimpse at one of the ways the professor invites females into his classroom discourse – through clear equitable use of language:

> The professor speaks to everyone in a very clear manner. Additionally, he doesn't use those damn sports analogies all the time like every other male professor I've had – from math, to management, to writing, etc. Thank you!

Other students report about how the course structure both supports and promotes their participation. They realize the positive impacts group work has had on their learning and interest. Excerpts from student interviews and written responses better illuminate these conclusions:

> I think that the interactive part of the class is good because it forces me to participate and learn the concepts. In previous science classes I was able to "get by" without participation.

> I like the in-class exercises because they help to clarify the material and allow us to practice applying the material to what we've learned that particular day.

> The group work is a great advantage. It makes things that you may not understand stick out and you are able to get help from different people and learn in different ways.

> He promotes group work, which makes the work more fun and allows peer teaching.

In the above quotes, the females clearly recognize cooperative group work as a place to talk and share ideas. Specifically, they offer insights into why the cooperative groups are effective. Females report that in that setting they now participate, practice what they have learned, learn in new ways, and experience peer teaching.

One element from Table 2, frequent discussion, though recorded evident during classroom observations and from the professor's interviews, was not corroborated by the female students. In fact, 7 of 9 interviewees suggested increasing class discussion when asked how they might change the course. Several students wrote similar comments in their responses to

Question 4 on the Female Impressions Survey. Students' comments regarding the amount of discussion follow:

> There's not a lot of discussion, he tries, but it doesn't happen because there are too many students. It should be more integrated in.
>
> It needs to be a smaller class, but I'd want a professor and not a TA, and to get more individual attention. This course has no discussion.
>
> I wish we had a discussion or some other way to help retain the information.
>
> I wish we had more teaching assistants around to talk to after class.

Females in this course clearly recognize the limits to quality discussion in a large lecture hall setting. They also do not easily accept its absence. These quotes importantly contain the wishes and needs of female students in a large class in which they feel included, yet experience frustration with a structure that limits their full engagement. One female student even went so far as to describe a complex way the class/seating could be re-arranged to allow for greater discussion.

An additional piece to the topic of discourse comes from the CETP end-of-the-semester (Fall 1999) survey indicating that fewer females than males (19% to 42%, respectively) felt encouraged to think about their own learning. That data, coupled with the written responses and interview statements suggest that females in the course need more *"voice where it counts"*, that is, with the professor. Female voices, though heard often in the context of a large lecture hall, asking brief questions and answering solution-based questions, are silenced (Gilligan, 1990). Few mechanisms exist for their impressions, reflections, or scientific musings, as a whole, to be meaningfully heard by the professor (Lewis & Simon, 1986). Females realize that being encouraged to think about one's own learning requires not only peer interaction, but also active

listening and discussion with an expert, someone who understands when and where to interject relevant questions and ideas.

The professor is keenly aware of the need to more effectively access student thinking. He conducts interactive lectures and engages in dialogue with students as the class structure allows. Despite these efforts, females need even greater reflective-type interaction with the professor. Ways to begin mediating this difficult aspect of a large lecture-based course call for (a) creative re-organization of class groupings (i.e. have TA monitor half of the class while the professor holds a short discussion section with the other half), (b) increased use and numbers of teaching assistants, (c) explicit and frequent offerings for office hour discussions, (d) exchanging homework assignments for reflective essays, (e) soliciting student comment cards, (f) creating out-of-class female study groups, and (g) promoting in-class reporting of conceptions and misconceptions. Unfortunately, class size may be too strong a limiting factor to make significant changes on this issue. Still and all, such changes appear necessary and as females learn more through higher quality engagement they will most likely find a sense of course relevancy in their personal and professional lives.

Major Theme of Inclusive Pedagogy: Strives for Relevancy

Feminist pedagogy research demands relevancy within the realm of a female's learning experience in science (Roychoudhury, et al., 1995; Mayberry & Rees, 1997). Throughout this study, student reported interest in science is linked to student's sense of the course's relevancy to their daily lives and careers. In responding to the Female Impressions Survey, 33% of the females agreed that the course increased their interest in science, 33% were not sure, and 33% disagreed that it had. Chi-square tests showed significance in the following findings: 33% of females who agreed that the professor motivated them to learn and 32% of females who agreed that they had learned more in this course than in other science courses were *not sure* or *disagreed*

that their interest in science had increased. In other words, a third of the respondents were motivated to learn, and a third agreed that their learning in this course was better than in other courses, yet they were not sure or disagreed that their interest in science had increased. These results raise important questions. Primarily, of course, can we rightly link science interest with a sense of relevancy? Secondly, supposing for this study that we can make the link, what is the use of having students take a general education science course that fails to increase their science interest, i.e. offer relevance to their lives? What then is the point of general education? When and how will non-science majors comprehend the significance of science issues in their lives and careers if it is not through courses of this type? Shamos (1995), arguing against "mainstream" definitions of science literacy speaks to this issue, "Good school performance, even a reasonable level of scientific literacy while one is a student, provides no assurance that the individual will retain enough science when he or she becomes a responsible adult" (pp.74-75). The data from this study describe a course that stresses and supports academic learning but needs to seriously consider questions concerning knowledge retention and relevancy.

Of course, elements of relevancy (see Table 2) were evident in aspects of the course, specifically; (a) makes links to everyday life, (b) uses a variety of resources, and (c) portrays female scientists and leaders in resource materials. Of these elements, however, only the second, *uses of a variety of resources* was apparent in all data sources. This was apparent during the professor's lecture/discussion multi-media presentation as images were presented from a wide variety of resources. Such presentations, combined with the cooperative group workbook, the textbook and OWL homework assignments added to students' overall sense that a variety of resources were utilized by the professor. One student succinctly explains this:

> I love the visual aids. The computer images are excellent, it makes the class run smoothly. I would never have the opportunity to view satellite images if I hadn't taken this course.

The value of using a variety of resources allows students to learn multiple perspectives on a topic and consider broader issues and a deeper significance about the topic. Females feel more connected to topics and activities when learning occurs through multiple perspectives (Harding, 1991). Through these resources, classroom observations witnessed the course making links to everyday life. For example, a focus on "habitats and natural hazards, resources and issues of global change"(syllabus) was evident during the observations. A video about the erosion of the coastline in Massachusetts was shown to students. These topics afford students personal relevance to the subject material. Unfortunately, it can be argued that, even with these offerings the 92% of the non-science major females taking the course described a course that lacked personal and professional relevance in their lives. Of all the data collected, only one female volunteered unsolicited information about the course's relevancy.

> This has been a course where I actually apply certain instances in the classroom to real life. Noticing high tides, low tides, the different angle of the moon and sun.

The professor's goal of science literacy is exemplified in that student quote. However, the idea of relevancy appeared cognitively difficult for most students to comprehend. When asked in interviews what they now know about the Earth, a variety of responses were hesitantly offered. No students made explicit statements about how their science learning informed future careers or problem-solving situations (excluding the Earth Science major). Student comments on relevancy follow:

> It's an interesting course, but the information is not important to me because I don't need it in my career. (Hotel/restaurant management)

> Many of the things are relevant, since I spend quite a bit of time at the ocean, I think that what I have learned is relevant, but it seems in this day in age,

knowledge about nature is not necessary, unless you are a specific type of scientist. (Elementary Education major/sociology)

The course was not personally relevant beyond the fact that I had/have a personal interest in the subject. I have no idea how it may impact my future. (Business major)

It (the course) helped me to get my gen-ed requirements, and I learned a bit about the oceans, which although it may not be terribly useful knowledge for my line of work, it is interesting. (Elementary education/communications major)

It is probable that these students had never considered the relevant links of their learning to their lives, and perhaps with deeper reflection, they could make the connections that seem to obvious to those in the scientific community. However, because it is primarily an information-based course (no labs or field trips) delivered in a scientific context of research and discovery, students appear to have great difficulty linking the learning with their lives. The above quotes represent student understanding that is devoid of personal usefulness and fairly encyclopedic in nature. These quotes may reflect the de-contextualized nature of knowledge presentation. Explicit links to the majority of students' future careers in the social sciences, humanities, and business do not appear to exist.

The data promote that the course strives for a greater sense of relevancy for female students. Consideration of the elements of relevancy from Table 2 can assist this effort. Changes and enhancements in the curriculum include the following four recommendations. One, pare down scientific content and focus on socioeconomic/gender related topics. For example, content needs to include social and problem-solving scenarios from female experiences and careers (Rosser, 1990; Harding, 1991). For example, the topic of overfishing could be situated in a discussion of the social and economical issues affecting families, communities, and businesses when fish processing plants close. Additions to the curriculum should also include female contributions to the knowledge of the oceans. Next, add a hands-on element to the class. All

students will benefit from opportunities to manipulate common materials, such as samples of ocean life, sediment, and rock (Rosser, 1990). These objects could be passed through a class of 300 students in an hour and fifteen-minutes. Student groups could, for example, quickly record questions and observations about the samples. Third, considerations should be made to include long-term projects in the requirements to allow for greater personal bonding with the topics (Rosser, 1990). At minimum, students could reflect on on-line oceanographic data during the semester and report on their findings using an electronic format. Finally, a small percentage of females commented negatively on the lecture hall (temperature, lighting, and seating). Affecting change in the physical learning environment is a challenging institutional issue. The instructors could request locating the class in a different building with a more stimulating environment.

Conclusions and Implications

This project describes the impact of a revised introductory-level college science course on females' impressions of learning. It situates female learning in the realm of inclusive pedagogy and links the major themes of classroom power, relevancy, and discourse to the described reform effort.

As reported by the females in the study, they feel promoted and encouraged to learn science as students in this course. Females felt included in the class and motivated to learn and thus a door was opened into the scientific community. Classroom observations reveal a revised curriculum offering students opportunities for self and group directed learning as well class participation. The professor's personality, unrelated to the curriculum, plays a huge role in these achievements. Findings reveal that elements of a balance of classroom power were evident in the curriculum as a result of (a) the professor's enthusiastic and approachable manner and (b) his ability to promote care and interest in student learning, as well as (c) the use of collaborative

groups (for learning and assessment). Collaborative group work occurring after lecture was observed to be a highly motivating activity for all students. The groups' discourse gave voice to females and balanced the play of power in the classroom by allowing students opportunities to construct their own meaning. Elements of relevancy are evident in the curriculum. Students comment that they are now more knowledgeable about the oceans in a general sense.

To achieve a greater balance of classroom power, the curriculum needs to address the lack of student-directed learning, syllabus open-endedness (Roychoudhury, et al., 1995), explicitness of the "science-as-usual" phenomena (Harding, 1991), and opportunities for individual reflection through, for example, imaginative writing (Hildebrand, 1998). The professor and course as whole are challenged to make more explicit connections between content, intended learning outcomes, and personal relevancy. Efforts to give females voice where voice counts, that is, with the professor are needed. Creative re-thinking of the possibilities of what *can* occur with 300 students during class should occur using the following questions as a guide. How can the professor negotiate the syllabus' direction and progression with student input? Where, when and how can the professor increase his attention to female ideas and impressions of their learning? How can content material be changed and enhanced to (a) introduce topics within a social context more closely related to the daily lives and futures of the female students and (b) better reflect the nature of science? What additional activities can cooperative groups engage in to increase individual reflection and allow for the manipulation of materials? How can the professor increase class discussion?

Finally, this project reminds us of the need to critically examine the findings of science education reform efforts. Project evaluations that do not consider the impact of reform on marginalized groups may too often oversimplify positive results. Consequently, additional

research is needed to describe the experience of different learning groups within this study, as well as many other lauded science education reform efforts.

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DAUGHTERS WITH DISABILTIES: A PROFESSIONAL DEVELOPMENT MODEL TO REFRAME SCIENCE, MATH, AND TECHNOLOGY EDUCATION FOR GIRLS WITH DISABILITIES

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As many regular and special education teachers will readily agree, providing appropriate instruction in the areas of science, math, and technology to children with disabilities can be a challenging, and often un-expected experience. For instance, one student in the Under-graduate Program in Special Education at Temple University described it this way:

> My first visit to the school was an eye-opener. It just freaked me out to think that I could some day teach in a setting like the one I was exposed to. The children seemed like okay kids, but they were not in a situation that facilitated learning. Instead, they were in situations that they were guaranteed to fail in.

A second adult in the same undergraduate program responded by saying that:

> I think that the most memorable thing [to me] was our speaker telling us that if [we] are going to do science right we should be prepared to get messy. I could not agree with her more. The best way for the children to learn science is to do it. One last thing that I learned is that you can adapt any piece of equipment to make virtually any lesson work for all special students.

A third future special education teacher provided more insights into this topic by explaining that: "Overall, my first visit was a very positive experience. It was a benefit to be able to watch an experienced teacher at work. I watched and learned as she made on

the spot changes to the lesson, assisted the students and altered the lesson just slightly to work on other mathematical concepts."

What do these three comments have in common? They all eloquently capture many of the startling ideas and insights that we found during our first year in an urban public school district as part of our work with our new National Science Foundation Project called "Daughters with Disabilities." In addition, these quotes illustrate many of the surprises and confirm many of the trends currently found in the professional literature on science, math, and technology education for students with disabilities.

As a result, the focus of this article is twofold. First, we hope to share with a broader audience a summary of our findings from our first year's efforts. Second, we want to raise questions, while continuing the critical dialogue about the challenges and benefits that classroom teachers face every day when they struggle to teach science, math, and technology to students in special education programs. A special emphasis throughout this article will also be placed on an area that we discovered has received little or no attention in the special or regular education literature--the unique, educational needs of girls with disabilities in elementary or middle schools. Consequently, while our work is being carried out in an inner-city, urban school district, we firmly believe that this information raises provocative questions and ideas for teachers, administrators, and parents in other educational settings as well.

<u>Breaking Down Barriers</u>

Daughters with Disabilities was created to specifically address the fact that individuals with disabilities, especially girls, have been widely under-served and under-educated in the areas of science, math, and technology (Cawley, Kahn, and Tedesco,

1989; Donahue & Zigmond, 1986; Mastorpieri & Scruggs, 1991; NSF, 1996; Shewey, 1997; Stefanich & Dodd, 1994). This disturbing trend has its roots in a simple conclusion: Today the vast majority of the 5.3 million American children or youth in special education programs are receiving inadequate or no education in the areas of science, math, and technology (SEMT). A logical outcome of such poor SEMT educational experiences is the negative way that students with disabilities often perceive science and math--either they have no further interest in these areas or they are denied the opportunities to pursue further education because of their limited or non-existent knowledge base (Kaye, 1997; U. S. Department of Education, 1991; Stefanich; 1994).

An even more serious consequence is they do not consider higher education as an option. For instance, the U. S. Department of Education (1997) states that in 1992-93 only 6.3% of undergraduates and 4.0% of graduate students identified themselves as having disabilities. Such limited educational possibilities, in turn, restrict their lives as adults even more, as they cannot become practicing scientists, engineers, or math teachers. We also believe that this negative trend reflects a significant gender bias.

As Shewey (1997) explained:

> Although women, minorities, and persons with disabilities have made great progress integrating the science world, a disparity still exists in their representation in the science community. In every ethnic group, women still comprise a lower percentage of science and engineering students and professionals than men. These gaps grow larger with age and prominent career positions. Once they reach college, women are 10% less likely to choose a science or engineering major and much less likely to obtain a Ph.D. Women [now] comprise 30% of science and engineering Ph.D. candidates, which is an increase of 5% since 1983. (p.1)

Consequently, the major focus of our project was to encourage more girls with disabilities from five, inner-city schools to prepare for the careers in Science, Math, and Technology by: (a) Increasing the interest and achievement in Science, Math, and Technology of girls in special education classes at the five participating schools; (b) Enhancing existing Science, Math, and Technology curricula for girls with disabilities in urban settings; (c) Introducing and teaching the concept of "pre-transition" knowledge (i.e., future post-secondary education awareness and career exploration through various activities, experiences, mentors strategies, etc.) in the SEMT areas; and

(d) Creating a network of support and training for pre-service and in-service special and regular education teachers, families, and community members in the areas of Science, Math, and Technology that stressed gender-sensitive curricula, instructional modifications, and successful inclusive education.

This focus was supported by a variety of related activities (e.g., summer programs, summer teacher training, the Saturday Academy, professional development, undergraduate teacher training, outreach to schools, materials dissemination, one-to-one consultation to participating teachers and schools). In addition, the focus was clearly founded on the following goals: (a) To enhance the existing SEMT curriculum through specific activities and learning methods shown to increase girls' with disabilities interest and achievement in science, math, and technology; (b) To facilitate interest and achievement in science, math, and technology among elementary school girls with disabilities; (c) To involve Temple University undergraduate elementary education, science or math education, and special education students in practical hands-on experiences at selected urban, elementary schools; (d) To involve elementary regular and

special education teachers, principals, and paraprofessionals in practical hands-on knowledge and activities in their home schools; and (e) To increase the knowledge and participation of families and care-givers of daughters with disabilities in terms of their science, math, and technological education.

Rationale for Daughters with Disabilities

Innovative projects like Daughters with Disabilities are not created in isolation. In fact, throughout our work, we have constantly referred back to the valuable information already available in the extant literature base. While we were often disturbed by the negative trends found previously by researchers in this area, we also discovered much valuable guidance to assist us as we went "into the trenches" in one, urban school district. For instance, there was clear consensus by professionals on the following three trends that were often repeated by educators who saw students with special needs in a variety of settings.

Gender

The first hurdle that girls with disabilities face in inner-city, public schools is that they are female. Research studies (AAUW, 1992; Baker & Leary, 1995; Evans, Whigham, & Wang, 1995; Hammrich, 1996; NSF, 1990; Wilson, & Milson, 1993) have documented the wide gender gap in achievement scores between girls and boys in the areas of science and math. These authors assert that when girls are allowed to work in a manner that is intrinsic to their collective learning style, appropriate science and math learning takes place.

Their work is support by other professionals who have demonstrated that girls frequently have different parental, cultural, and educational experiences than boys

(Bailey, 1993; Kahle & Lakes, 1983; Liaw, 1990; Rosser, 1990; Sjoberg & Imsen, 1988). For instance, some researchers refer to the concept of "selective perception" observed in parents of newborn babies, where parents will perceive differences in infants based solely on the baby's sex. In one study by Rubin and his colleagues in 1974, 30 pairs of first time parents (one half with newborn daughters and one half with sons) were asked to describe their child in the first 24 hours after birth. The researchers reported that girls were rated by their parents as being significantly softer, finer featured, smaller, and more inattentive even though no actual differences in size and weight were found between the male and female newborns. Skolnick, Langbort, and Day (1982) went one step further to describe how these early stereo-types can be translated into the classroom:

> Most elementary teachers will tell you they have more occasion to praise little girls than little boys. But the qualities rewarded in the two sexes are very different. While boys are usually praised for intellectual work, girls are mostly praised for behaving properly and obeying rules of form. They are encouraged to be compliant but not necessarily to be creative, autonomous, or analytic. As a result, they learn they re pleasing but not necessarily that they are capable. (pp. 19, 20)

Such varied experiences will often shape other daily interactions with adults. For example, research has shown that girls tend to rely more on the opinions of others than boys and boys were observed to be frequently encouraged by their parents to solve their own problems first, while girls will receive assistance to solve problems. Skolnick, Langbort, and Day also stressed that:

> There is a mystique about mathematics [and science] that implies that either you have what it takes or you don't. This notion is all too compatible with social messages about female inability. Many girls believe that they simply lack the particular talent, rather than the practice, that permits success. To dissolve the

> mystique, girls need to do what boys do--practice.
> As they experience success, they will gain credibility
> with themselves as math and science learners. (1982, p. 23)

It is interesting to note that our own efforts at Temple University have supported this thesis. For instance, we found that if girls are given the opportunity to learn in an environment where they felt their voice is heard, they obviously enjoyed science, while simultaneously demonstrating an increase in their self-esteem and identity (Hammrich, 1998).

It is interesting to note that recent data points to another, hidden area where gender may shape the SEMT experiences for girls with disabilities. New studies have emphasized the role of mothers in educational levels in relation to special educational needs. For instance, George (1996) has found that lower parent educational experiences--especially for mothers--is a significant predictor of how and when students will receive special education. In fact, children whose mothers completed college will receive special education over two years earlier in their educational profile than those whose mothers only finished the eighth grade. In addition, parental educational experiences (and maternal intelligence) seem to be directly tied to inner-city settings (George, 1996; OCR, 1992). Peng (1992) found that 22% of the families in inner-city settings dropped out of high school in comparison to an 8% secondary drop-out rate for the families who lived in other urban/suburban areas. As a result, if parents are high school drop-outs themselves, it may make it much more difficult for their daughters to see them as role models for further SEMT education or careers.

Ethnicity and Urban Education. Gender is usually only the first hurdle that girls with disabilities face in the American public educational system. The second equally important hurdle is where their education takes place. For instance, although only 8% of all U. S. school districts (like the one where Daughters with Disabilities takes place) have been classified as inner-city, these same public schools educate over 26% (or one fourth) of all American school children (OCR, 1992). And one of the key characteristics of many inner-city neighborhoods like the one served by Daughters with Disabilities is a high poverty rate. Socio-economic status is a critical factor because poverty is a common condition for many students with disabilities, especially those like the participants in Daughters with Disabilities. Many studies have shown that these three factors--poverty, disabilities, and inner-city settings--have strongly interconnected ties to each other (Ahren, 1995; OCR, 1992; Peng, 1992; Wagner, 1995). For example, as George (1996) says, "Mild mental retardation is consistently reported to be associated with low socioeconomic status and race. . . . Socio-economic status may [also] account for some of the disproportionate representation of African American children in that category." (p. 1)

In addition, often schools in inner-city settings do not have the resources to provide an adequate special education program for special needs students. As George (1996) explains, the provision of appropriate [special education] services rests in part on the districts ability to obtain an adequate supply of qualified personnel, to select appropriate curriculum and instructional methods, and to maintain active parent involvement (p. 4). As studies and testimonials in Section C below underscore, such supports rarely happen. In fact, OCR data (1992) has shown that most inner-city students with disabilities are very likely to be placed in the most restrictive, least appropriate

environment, as a segregated resource room is all that is available to meet her needs (e.g., 43% of the students versus 23% of the students in non-urban areas).

Such restrictive, out-dated, educational practices are further complicated by inner city schools that traditionally are burdened by such negative factors as: lack of funds, over-crowded classrooms, out-dated or non-existent laboratory equipment, few technology resources, and over-worked, ill-prepared teachers in the SEMT area (George, 1996; Rivera, 1997; Mastropieri, Scruggs, & Shiah, 1991, Mastropieri & Scruggs, 1992). It is no wonder then that nearly half of the high school students in the inner-city district where our participants live are failing their science and math courses. In 1991 for instance, only 55% of the 9th-12th grade students received course credit in math or 57% in science.

Disability

But girls with disabilities face a third hurdle that is often the most crucial to their success as adults. Whether they are taught in the traditional, out-dated, resource room (where they are usually completely segregated from their peers) or included into regular classes, they usually will not find the resources available for an adequate science and math education. All too frequently, students in special education classes are losers when it comes to any science or math education that will address their special needs (Rivera, 1997; Mastropieri, Scruggs, & Shiah, 1991, Mastropieri & Scruggs, 1992; Ysseldyke, Thurlow, Wortruba, & Nanaia, 1990). First, there usually is a shortage of teachers trained in special education in inner-city settings. As George (1996) stresses:

> Recruiting and retaining qualified teachers and related service providers is critical to meeting students educational needs. Although special education teachers are in short supply in many places, the shortages are particularly severe

> in inner-city areas. Thirty -eight percent of all public schools had teaching vacancies in special education in 1990-1991. . . .[with a] 42 percent in inner cities. Public school administrators said that vacancies in special education were among the most difficult to fill, with 26 % of the schools finding them very difficult or impossible. (p. 6)

This disturbing trend is clearly illustrated in most resource rooms, where typically only math facts are drilled and re-drilled in a tutorial manner. Often, basic remediation is the extent of the math curricula for students with a variety of special needs and disabilities. Also, due to the heavy emphasis on basic literacy and life skill development in resource rooms, science is usually completely neglected altogether (Rivera, 1997; Mastropieri, Scruggs, & Shiah, 1991, Mastropieri & Scruggs, 1992). Even if the special education teacher attempts to teach science or integrate math and technology into lesson plans, s/he is usually not prepared or poorly trained in these critical areas (Baker & Zigmond, 1990; Balzer & Roberts, 1993; Ysseldyke, Thurlow, Wortruba, & Nanaia, 1990). As Stefanich (1994) explains, "Most university programs which required preparation for exceptional students provided a general course with a focus on definitions of exceptionalities and special education legislation, but with little or no [science] methodology" (p. v.).

In fact, even if students with disabilities are gvien access to more inclusive settings, the SEMT educational picture for them in regular classes is usually not much better. For example, it is interesting to note that over half of all students (approximately 2.7 million children) with disabilities currently get their science and math education in regular classrooms (Kaye, 1997; U. S. Department of Education, 1991). But, the professional literature stresses that while regular classes are taught by teachers who may

be competent in teaching science and math to regular students, they frequently have virtually no idea how to teach students with disabilities.

As Stefanich stresses:

> The general classroom teacher of science receives little or no academic coursework on meeting the needs of special students and are seldom afforded opportunities to teach these students in preservice or graduate teacher preparation programs" (p. v.). Based on her personal experience teaching a student with a disability in a regular science class who required a wheelchair, Bazler says that: "I still make the classic mistake of isolating the student [with disabilities] from other classmates rather than making her an integral part of the class. . . Students [with disabilities]. . . are a fact of life, but many teachers are anxious, fearful and unsure of how to meet their special needs (p. 302, Bazler & Roberts, 1993).

It is important to compare this negative picture with the current, substantial research base which clearly demonstrates how girls can succeed in environments that are specially structured to meet their special needs (Leaf, 1994; Norman & Caseau, 1994; Stefanich and Dodds, 1994). This literature shows that it is critical to ensure that appropriate supports are available to promote the resilience of students with disabilities, especially girls, in science and mathematics (AAAS, 1991a; AAAS, 1991b; AAAS, 1991c; Burgstahler, 1994; Burgstahler, 1996; Burgstahler, 1997; Hammrich, 1996; Hammrich, 1997).

A New Instructional Model for Girls with Disabilities

The attempt to address these sobering statistics in a proactive, positive way quickly became the heart of Daughters with Disabilities. To meet the complex needs of such a significant problem, our Project used a multi-faceted approach that stressed a variety of activities, materials, and strategies that were applicable to the science, math,

and technology needs of girls with disabilities while also being gender-sensitive and culturally relevant. This new model was also clearly rooted in two other projects also funded by the National Science Foundation: Sisters In Science (SIS) and Project DO-IT, along with our other collaborative partners from the American Association for the Advancement of Science (AAAS). Examples of the activities and materials available to the five participating schools through Daughters with Disabilities during the first year included:

1. Teacher Training. Teachers were taught how to deliver instruction that was based on the "best practices" for inclusionary settings for elementary aged girls with a wide range of disabilities. (Special emphasis was placed on materials, strategies, and lesson plans previously developed and tested in elemmentary classrooms by Sisters in Science and AAAS.) Also, a beginning emphasis was placed on integrating pre-transition methods and materials for SEMT education and careers into special education instruction through materials from SIS and Project DO-It.

2. Classroom Activities and Outreach to Schools. During the first year, a wide variety of classroom activities and supports were available in fourteen special education classrooms in the five participating elementary schools. Approximately 36 students from the Temple graduate and undergraduate certification program in special education made on-site visits to each class. Based on individual student needs and teacher suggestions, each teacher-in-training gave one-to-one support as requested. For instance, some students observed the classroom as a whole while others tutored individual students on specific classroom activities that stressed math skills. Other students used a simple cooking lesson to teach the students about such basic concepts as using your senses to

observe changes, measuring ingredients to discover which is heavier or lighter, and using basic mathematics to increase or decrease a recipe. These activities were so successful that the pre-service teachers were invited back into the classrooms for a second year to continue interacting with a new set of 4th and 5th grade students.

3. Saturday Activities. The Saturday program was held for the girls on the Temple University campus one Saturday per month during the regular school year in the morning for three hours per session. To promote inclusion when-ever possible, a collaborative model was utilized. The girls from Daughters with Disabilities were taught by the same staff and used the same lessons from Sisters In Science. The Saturday Coordinators, undergraduate special education students, and volunteers' facilitate the program. Activities include environmental service learning projects and reflection sessions. Girls with disabilities were fully integrated into all activities, but also received individual support as needed. An example activity was a lesson plan that stressed using ratio proportions where girls created a giant hand that was based on comparisons to their own body dimensions.

4. Summer Program. A two-week summer program was conducted by staff from Sisters in Science for girls both with and without disabilities on the Temple University Campus, along with a simultaneous, three day, intensive Teacher Training for special education teachers, principals, paraprofessionals, and parents from the participating schools. The focus of the summer program was urban water-ways, with a special emphasis on how water impacts our daily lives in myriad ways in an inner-city environment. An example activity included designing model rivers and testing the effects of run-off, acid rain, and so forth.

5. Undergraduate Teacher Preparation. Approximately 70 students in regular and special education classes at Temple University were exposed to best teaching practices in the areas of science, math and technology as part of two Special Education methods and one General Education theory courses. Special emphasis was placed whenever possible to underscore how to most effectively teach girls with disabilities in inner-city schools in these critical areas, especially in inclusive settings if possible. Numerous activities were completed by the undergraduates including: a) two visits or more to one of the target schools in Daughters with Disabilities (including such experiences as: formal classroom observation concerning gender equity, math/ science teaching, and inclusion, continued volunteer work with specific students as requested by the teacher, teaching a science/math lesson to the whole special education class, etc.); b) participation in debriefing meetings for follow-up comments and questions led by Temple University faculty; c) hands-on experiences with science/math materials and lesson plans applicable to girls with disabilities in inner city schools as demonstrated by two different consultants and instructors (Dr. Penny Hammrich from Temple University and Laureen Summers from AAAS); d) on-line communication with an assigned DO-IT mentor (i.e., a college student from the University of Washington or working professional in the Seattle area who has a disability and is actively involved in the areas of math, science, or technology) to discuss inclusive SEMT education, career preparation, and disability related issues and accommodations; and (e) the development of a case study and personalized teaching material for one of the students observed during the classroom visits.

Science, Math, and Technology Curricula and Experiences

Each of the previously described components of the program clearly centered around promoting gender sensitive approaches to teaching science and mathematics in inclusive settings for girls both with and without disabilities. As a result, one important facet of teaching strategies and approaches used with girls involved in both Sisters in Science and Daughters with Disabiltiies facilitated an environment that was directly relevant to their lives, accommodating, noncompetitive, cooperative, and respectful of their opinions both as females and as elementary students. In addition to infusing this crucial educational philosophy throughout all activities and curricula, all experiences in both Projects stressed the development of science and math process skills such as: observations, communication, classification, and experimentation. Also, as previous research suggested that when girls find science and mathematics relevant to their lives, they will achieve more in these areas, the activities that the girls both with and without disabilities participated in were directly shaped by the urban environment where the girls lived everyday. Examples of both this overall philosophy and how it was implemented into practice were illustrated by the experiential learning through the curricula from the Summer Academy and within individual lessons taught during the Saturday sessions of Sisters in Science, as described below.

Experiential Learning in the Summer Academy

While the overall theme of the two week Summer Academy held on the Temple University campus was "Water All Around Us", each component and individual lesson within the curricula was created in concert to provide the girls with a physical

environment that was both psychologically, emotionally and socially safe and accessible to all students. In addition, each activity clearly connected the SEMT subject matter to real-world issues that were culturally relevant to students. For instance, during each meeting, students were actively encouraged to: generate and gather data, pose scientific and mathematical problems, generate possible explanations and propose methods for evaluating the best explanations. Across all of the events, teacher, parents, volunteers, and Temple University students were providing a level of mentoring that extended the students learning base beyond the walls of the classroom.

It should also be stressed that all learning experiences and lessons were founded in constructivism. For instance, whereas in the past, a curriculum often meant a set of answers to be transferred from teacher to student, the curriculum created for the Summer Academy was framed around a set of questions posed to a class of elementary aged girls, both with and without disabilities (Skilton Sylvester, 1997,). In this way, the process of inquiry was equally constructed by the students and teachers to foster a true community of learners, while also remaining gender-sensitive, culturally relevant, and inclusive. Each learning adventure utilized real life situations to explore the subject matter in depth, such as the waterways of our urban setting. So instead of simply studying the names and structures of various bodies of water in isolation, the girls actively explored their own urban environment in a large, Eastern city (e.g., they mapped local waterways, visited the water treatment plant that processed their waste water, built model rivers, located various lakes, rivers and tributaries in their region, and tested the quality of water in their own neighborhood).

In addition to these exciting activities, each of the central studies of the program in general was structured around one or more central questions, which became a focal point for the whole group inquiry. The questions were woven from a fabric of unifying SEMT themes (i.e., systems, models, scale, constancy, and change) and cross-cutting competencies. The five cross-cutting SEMT competencies were: participatory citizenship, communication, multicultural competencies; problem-solving; and school-to-career.readiness, and technological literacy (School District of Philadelphia, 1996). The unifying themes constitute those skills that allow people to play effective roles in the community. These themes and competencies, along with related activities are summarized in Table 1.

Table 1.
A Comparison of Themes, Competencies, and Student Activities in a Series of Lessons on "City Rivers

SEMT Themes	SEMT Competencies*	Student Activities
Systems	Multi-Culturalism Participatory Citizenship	Explore city neighbohoods Visit water treatmentplant Visit Riverbend Environmental Educational Center
Models/ Scale	Communication Problem-solving	Build a scale model of a river Identify the water cycle
Constancy/ Change	School to Career Readiness	Study professionals who use water in their jobs Write local scientists
	Technological Literacy	Research water quality & use on the Internet

These competencies are from the Philadelphia Public School System. Curriculum Standards Framework

Numerous activities, strategies and experiences were implemented in the Summer Academy curricula about water to encourage the development of these themes and competencies. For example, within the context of the girls' exploration of city rivers, they learned about systems as seen in the water cycle. Along the way, the girls also discovered the three states of matter: liquid, solid, and gas--an important SEMT lesson, which is fundamental to the understanding of the concepts of constancy and change. During the two weeks, the girls studied models as they create their own rivers, while also utilizing the principle of scale.

In the study of city rivers mentioned above, students were guided to ask this central question: How do the city rivers get clean so that people can drink the water? In searching for answers to this question, the girls then visited a city water treatment plant. They also researched ways of making drinking water safe by finding sites on the Internet and wrote local scientists for their answers and suggestions to their important question. Related activities from the Summer Academy curriculum included: (a) cooperative student teams of girls who designed an experiment to purify samples of dirty water (each group then predicts, designs, experiments and communicates their results to the class); (b) a discussion led by adult, female, team leaders about the effects of reduction, reuse, recycling of water in their urban environment; (c) pairs of girls who created animal sanctuaries, habitats and rooftop biomes from craft materials and household objects to show the inter-relationships among humans, plants, and animals in a urban environment ; (d) an exploration with their group leaders about how to practicing water conservation in

their local, inner-city neighborhood; and (e) field trips to examine the effects of community involvement in local revitalization projects in their home environment.

Integrating Science Lessons and Inclusion. Clearly, one of the key strengths of Daughters with Disabilities was its on-going infusion of successful inclusive educational techniques, accommodations and strategies into the effective lessons that the staff from Sisters in Science previously developed to teach science, math, and technology to elementary-aged girls without disabilities. An example of this critical integration can be illustrated in the Sisters in Science lesson on measuring and graphing the density of familiar objects. Various components of the lesson, along with appropriate accommodations for girls with disabilities in inclusive classrooms have been summarized in Table 2.

Table 2.

Suggestions for Inclusive Education in a Science Lesson about Weight and Measurement

Specific Activity	Suggested Accommodations
▪ Fill out mystery object lab sheet	Do the activity with a peer Use a laptop computer to fill out sheet for both girls Lab partner acts as a scribe to fill out the lab sheet
▪ Manipulate objects and tools	Partner manipulates objects and tools to compensate for fine motor problems
▪ Verbal discussion and oral problem-solving	Partner sits at eye-level (for wheelchair) Encourage student to speak slowly Give both students extra time, if needed
▪ Measure each foil-covered mystery object	See number 2 above
▪ Rank each foil-covered mystery object	No accommodation needed
▪ Hypothesize about each object	No accommodation needed
▪ Graph the weight and rank of each object	See numbers 1 and 2 above

This information is based on a lesson plan originally developed by Sisters in Science.

Girls typically complete this Sisters in Science activity by forming pairs to fill out a mystery object lab sheet. Each pair is given 6 foil-covered objects to be measured and ranked on the sheet by weight. They are also told to guess what the object is and form a hypothesis about it. After removing the foil, they check their guesses. The also complete related activities on mass and volume using water, graduated cylinders and graph paper

for measurement and graphing. In addition, they will read Kim Hubbard's biography: a computer engineer at NASA.

A brief examination of this lesson shows that all students will be required to complete these skills and competencies: to follow several visual and auditory instructions; to use various tools for measurement; to speculate and hypothesize about the relationships and comparisons among the mystery objects; and to record the results, either by graphs or by written answers on the lab sheet. Students must also apply the cognitive concepts of lighter versus heavier weights and use mathematical reasoning for measuring, comparing, charting and graphing the objects as needed.

Obviously, each set of accommodations for this lesson will be personalized to meet the unique strengths and disabilities of each girl in the class. However, to further illustrate these suggestions, the following ideas might be useful for a girl with physical disabilities (i.e., has difficulty using her hands and uses a wheelchair) who is being taught this lesson in an inclusive classroom. If this student has fine motor difficulties, she could be assigned a partner either with or without disabilities to manipulate the objects and tools, as necessary. If she has problems with handwriting, the mystery lab sheet could have already been put into an adapted laptop computer by an aide or a classmate, so the responses can more easily be recorded for herself and her partner. If she uses a wheelchair for mobility, her partner, teacher, or the classroom aide should sit at eye-level for discussion purposes. Also, even though this student may be very sociable, if she has difficulty verbally expressing her thoughts when under stress, she should be encouraged to speak slowly or given extra time to complete the assignment with her partner. Throughout this lesson, it should be emphasized however, that both girls will be expected

to turn in the same high quality of work as the other teams. In addition, follow-up feedback will be given to the special education teacher and the girl's parents or caretakers, as requested.

First Year Findings

Such an innovative approach to teach the critical knowledge of science, math, and technology to girls with disabilities is clearly an important first step to address the often surprising and sobering findings that we found during our preliminary experiences in one urban school district. The following six findings became guideposts for us as we navigated the frequently confusing, but interesting world of special education for elementary students in public education today.

Gender Prevalence

The first overall finding that was a total surprise to us was the significant absence of girls in the special education programs in all five target schools. In fact, in our observations of the five target schools, we have estimated that an average of less than 20% (or the clear minority) of students in the special education classrooms were female. In addition, we found a few classrooms where there were no girls at all in the designated special education classes. This startling trend was reflected in an article written by a public school teacher who also observed the same phenomena in her classroom in the New York City Public School System. As Mosle (New York Times, 2000) described her third grade class:

> I had Room 306, indicating that I was teaching in the third grade and had the six or 'bottom', monolingual class. . . .I had twice as many boys as girls--not because boys are less intelligent than girls at that age, but because

> they they're rowdier. They get labeled behavior problems and are often put in the worst classes. . . And in truth, the class was challenging. Although Adam and Keemy were sociable and outgoing, they had severe learning disabilities and entered third grade still reading primers. (p. 25)

Mosle's observations could be describing the classes that we went into during our first year of Daughters with Disabilities. While we have no hard data at this time to support any speculations or reasons for the prevalence of boys in special education or remedial settings, this lack of girls became a constant pattern in our work in an urban, educational setting.

Disability Categories

In addition, to the lack of girls, it is important to note the composition of disabilities that we found in our designated special education classrooms. For instance, just as we discovered a majority of boys in each class, we also saw that a few, if any, of the students had either sensory, physical or significant disabilities. In fact, the vast majority of all students seen in the special education classes had mild learning or behavioral disabilities. They were served in this school system in classrooms designated as "Learning Support" (i.e., students with diagnosed learning disabilities) or "Emotional Support" (i.e., students with diagnosed with emotional behavior disorders). No students with significant physical and/or sensory disabilities we found in these schools could be beneficiaries of the resources and instruction from our project. It should also be noted that this trend was graphically illustrated for us when we discovered that only one of the original five schools that we had asked to participate in the project was accessible for individuals who use wheelchairs.

Special Education Teachers as Gatekeepers

A third, thought-provoking finding was the significant role that teachers played as gatekeepers in the recruitment of participants, and the implementation of the program in their classrooms in our five targeted schools. For instance, the first months of the program we spent on very intensive efforts to recruit special education girls to attend our program activities through personalized correspondence distributed by individual classroom teachers, due to confidentiality. But as time went by, we were surprised at the little response we were getting from the students and their families. Intrigued by this and searching for an explanation, we asked the teachers again for feedback and assistance. They told us informally that almost all of them felt that their students we not "good candidates" for the program, as their girls were "too low functioning to learn math, science, and technology."

That dialogue taught us a very valuable lesson--that these impressions were based on their own negative math and science school experiences, as well as their own lack of preparation in these areas. As a result, we designed personalized training sessions for the teachers as well as their students to stress hands on science and math activities, along with discussions on how to adapt SEMT lessons to a variety of disabilities. We discovered after these sessions that focused on what people with disabilities can achieve that teacher participation and enthusiasm increased significantly. This changed attitude, in turn, is starting to translate itself into new, more challenging curricula for students to use and the teachers to try out in their own classrooms in a variety of daily activities and lesson plans. Perhaps, the greatest benefit is that we have found that the teachers and

principals are becoming active partners to help us recruit more girls and parents into the program. We feel confident that these teachers will become our most valuable asset to act as communication facilitators between school, home, and Temple University.

Unusually High Turn-Over Rates for Special Education Teachers

Another unexpected and discouraging outcome found during our first year as an NSF project was the high turn over rate for special education teachers in the five participating schools. The national issue of retaining special education teachers in urban public schools is a problem that was not foreign to us, as it had already been explored in depth in the professional literature. But we never imagined that it would have such magnitude or a personal impact on our first year's activities. Based on informal testimonials from teachers and administrators, we found to our consternation that most special education positions in inner city schools like our targeted district were perceived by teachers as being temporary jobs while teachers waited for offers in either "better" schools or suburban districts. As a result, it was not unusual during Year 1 to find ourselves facing the immediate challenge of loosing two very committed teachers in the course of the first two months of our extensive work with them. In addition, by the end of Year 1, we found that approximately 40% of the teachers that started participating with Daughters with Disabilities had either been transferred to non-participating schools or had left our school district entirely. Such excessive mobility and retention issues required that we were continually going back to the beginning to recruit new teachers into our project.

Very Little Exposure to Science for Students in Special Education

A fifth, disturbing finding that has been already described by other professionals in the extant literature base was the total lack of any type of challenging science, math, or

technology education taking place for any students in our designated special education classrooms. In fact, both our on-site school observations and numerous formal and informal conversations with special education teachers clearly underscored that both boys and girls had little or no exposure to age-appropriate technology or science education. In addition, while mathematical lessons were taught in these classes, they definitely were remedial in nature and tone. Most were heavily based in rote learning with an emphasis on simplistic, limited activities and worksheets. It should be stressed that to our knowledge, no science education was taking place at all in any of the classrooms where we observed. However, some of the teachers were doing "science-related" activities (i.e., looking a the daily weather, discussing the seasons, describing a few plants or animals, etc.), but when we explored these curriculum topics with them, they clearly did not perceive these ideas as being "science" or "science-related". We also found that a few of the classrooms had computers, but we only observed limited, if any, technology-related activities. In addition, to our knowledge, none of the computers had any connection to the Internet. We can again speculate that such limited or non-existent SEMT education for girls with disabilities may have two inter-related causes: the teachers' and principals' own beliefs that special needs students are not able to learn math, science, and technology, along with the teacher's own lack of experience in these academic areas. (See previous findings for more information.) It should also be noted that none of the curricula or materials that we saw in the classrooms or reviewed to share with the teachers addressed the areas of gender-sensitivity or cultural relevance in terms of students with disabilities.

<u>The Lack of Teacher Preparation and Inservice Support</u>

It is logical to assume that the sixth finding from the first year of our efforts with Daughters with Disabilities would go hand-in-hand with the fifth finding discussed in the previous paragraph. As part of our on-going dialogue with the teachers, principals, and paraprofessionals in our five participating schools, we uncovered another disturbing trend that had been earlier reflected in the professional literature. It was the unanimous consensus among all professionals that we talked to that they were clearly under-prepared or totally unprepared to teach any science, math, or technology skills beyond the most basic remediation. For instance, when we recently asked them if they had felt prepared to teach science, math, or technology to students with disabilities before their participation with our Project, we discovered that: a) Only two of the nine teachers present felt prepared to teach science; b) Five of the nine teachers were prepared to teach math; and c) One of the nine teachers felt competent to teach technology to her students.

We also learned that many of the teachers who had been responsible for special education classes for many years had trouble remembering any support that they had received in terms of appropriate science or technology education. To probe further, we asked all the participating teachers and principals if they could remember any pre-professional training in science skills for students with or without disabilities. All of our participants (except one principal who herself was a former science teacher) drew a complete blank.

To further underscore this need, we were often astonished and touched to see how hungry these same professionals were to receive specific materials and strategies to use in their classrooms. For example, after completing their Sisters-In-Science lessons during one training session, the teachers told us that they never believed that science and math

could be so much fun. They also applauded the use of common, household materials to teach science and math. In addition, they eagerly requested catalogues to order materials. They also asked for follow-up lesson plans to explore further with their students a wide variety of basic science topics and experiments (e.g., gravity, force, and motion; electricity; magnetism, weather forecasting; chemical changes to matter; urban ecology; and cooking). The teachers repeatedly told us that they were learning as much as their students. As one teacher aptly summed up her experiences: "This is a whole new world. . . .I can bring so much to my students, even though [sometimes] they may be too low [cognitively] to do most of the science. . . .But this translates well into all of my teaching".

Conclusion

As the previous information has shown, in the future we plan to chip away at the obstacles that we found during our first year with one girl at a time, one teacher at a time, and one school at a time to give as many girls as possible the long-lasting benefits of an appropriate education in science, math, and technology. When we look back on our first year's work, we discovered that just as there was often a total absence of any appropriate science, math, or technology instruction for girls with disabilities in our targeted classrooms, there was an equal enthusiasm by the girls and their teachers to learn this new information when they had the tools and training to access it. Perhaps, one of the Temple undergraduates summarized it best for all of us when she said:

> I learned [from participating with Daughters with Disabilities] that teaching science isn't as difficult and scary as I once thought. I grew up hating science. I was never good at it through school and out of that developed a fear of teaching it . . . . I knew that I wasn't strong in science and I was constantly worried that the students would ask me a question that I

> couldn't answer. . . This experience has changed my preconceptions of science 180 degrees. I no longer think that science is boring. In fact I think that science is very exciting. . . I learned so much from doing these experiments but most importantly that science is FUN! I also learned that there is a place for women and girls in the field of science.

In conclusion, one project or one group of committed science, math, or special educators alone cannot tear down all of the barriers for girls with disabilities in the areas of science, math, and technology. One set of dedicated teachers, mentors, or undergraduates by themselves cannot change the often negative course of employment or post-secondary education for future female scientists or mathematicians with disabilities previously described in the professional literature. But this project clearly is a start. For girls with disabilities, the concentrated, personalized efforts of Daughters with Disabilities can be a significant tool to accomplish many, important objectives. For example, participation in project activities and the dissemination of project materials will clearly raise vital SEMT issues and suggest powerful solutions to a wide variety of critical audiences (e.g., future science, math, and special education teachers; parents of girls with disabilities; current regular education and special educators; administrators, paraprofessionals, and related staff in urban settings; college faculty, and so forth). On-going, pro-active involvement by the girls themselves can both teach important science and math skills, while simultaneously expanding new horizons through early transition awareness.

Sisters in Science has repeatedly shown that these successful experiences can happen for girls in elementary classes who are not formally diagnosed with disabilities. Isn't it time that these same, powerful experiences and materials be available to their classmates with disabilities as well?

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THE LEVELS OF ACCESSIBILITY MATRIX SYSTEM FOR DETERMINING THE APPROPRIATENESS OF HANDS-ON SCIENCE ACTIVITIES FOR STUDENTS WITH DISABILITIES

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Overview

With the advent of laws governing special education, science methods courses must prepare teachers to address the needs of all students, including those with disabilities. In part, we need to help our preservice teachers think through the nature of hands-on science activities to plan for making them accessible to students with disabilities. This paper reports our work to date on development of a Levels of Accessibility Matrix (LAM) system, a guide for selecting and planning appropriate science activities for inclusion of students with disabilities, particularly sensory or motor disabilities.

We devised the LAM system out of need that arose in planning and conducting hands-on science activities for Ocean of Potentiality Science camps for adolescent youth with moderate to profound disabilities (Klemm, 1999; Klemm, Radtke & Skouge, 2000). We are committed to making these camps fully accessible to all youth with disabilities. However, we lacked a systematic way to determine the accessibility of hands-on activities for use as camp science activities. During one of these science camps, we asked the youth campers to provide feedback to us on the accessibility of a series of hands-on activities investigating the concept of sound. From the Deaf students in particular, we learned that activities cannot merely be treated as "accessible" or "not accessible. For example, Deaf students are accomplished tactically in sensing sound vibrations, and some students with hearing impairment profound enough to require a sign language interpreter for communications could nevertheless hear sounds within certain

frequencies. In addition, the teaching techniques influenced accessibility. When thoughtfully implemented using peer cooperative learning and adult facilitators, hands-on activities could be made accessible to students with motor impairment, learning disabilities, and, for the most part, severe emotional disturbance and mental retardation (Klemm, Skouge, Radtke & Laszlo, 2000).

Based on feedback from students in these science camps plus our own prior classroom and teacher education experiences, we devised the LAM system to provide a basis for selecting, modifying, rejecting—or just plain discussing—hands-on science activities for students with disabilities. We devised the prototype Levels of Accessibility (LAM) system described below. Subsequently, we found LAM system useful in our secondary science methods course for engaging preservice science teachers in thinking through the accessibility of hands-on activities for students with moderate to profound disabilities who are mainstreamed into secondary science classes.

Levels of Accessibility.

The LAM system uses a grid, as show in Table 1. First we array the sensory modes of learning horizontally as follows: Visual (sight observations), Tactile (touch, manipulation and etc.), Sound (hearing or listening), Smell (odor), and, for some activities, Taste. Then we array the nature of the disabilities under consideration, e.g. Hearing Impairment/Deaf, Visual Impairment/Blind, Speech/Language Impairment, Orthopedic Impairments.

When analyzing the sensory accessibility of a hands-on science activitiy under consideration, we select either a type of disability (e.g., Hearing Impairment/ Deaf) or think about the accessibility of the activity for a specific learner's disability. Keeping that disability or specific student with disability in mind, we then rate the accessibility of that hands-on activity using the scaled accessibility level ratings shown with Table 1.

Table 1.
Sample Levels of Accessibility Matrix Table

Disability	Visual Input Accessibility	Tactile Input Accessibility	Auditory Input Accessibility	Motor Requirements Accessibility
Profound hearing impairment/Deaf				
Visual impairment/blind				
(List other disabilities)				

Note: Levels of accessiblity are rated as follows:

0 = Not Accessible (even with lab modifications and personal assistance)

1 = Might be Accessible (with lab modifications and personal assistance)

2 = Accessible (with lab modifications and personal assistance)

3 = Accessible (with lab modifications, no personal assistance required)

4 = FullyAccessible (without lab modifications or personal assistance)

We use the levels of accessibility rating scale to analyze specific activities and consider their sensory accessibility. For example, in an activity where learners investigate sound using tuning forks, we would systematically consider the accessibility of that activity for types learners who are sensory impaired (hearing impairment/Deaf, visual impairment/Blind, motor impairment and so on), or for specific learners with known impairment.

We focus on one type of disability (or student with specific disability) at a time to analyze the accessibility of the tuning fork activity for that disability (or specific learner with disability). To illustrate how this works, we use the specific example of a learner

who is severely hearing impaired. We then think about the types of sensory inputs available to the learner as he/she manipulates the tuning forks to listen to them, observe them, touch them (and perhaps even try to smell them.) fork activity. To illustrate, let's think about the auditory mode for a learner with profound hearing impairment. We know immediately, that the tuning fork activity is not LAM 4 (fully accessible) for learners with hearing impairments, and need to consider whether the tuning fork activity is Level 0 (not accessibile at all) for that learner. Knowing that some students with impairment can hear within specific ranges of frequency (e.g. high tones or low tones), it is possible that the tuning fork activity might be accessible (or partially accessible) at Level 1.

We further analyze the tuning fork activity for it other possible sensory inputs in a hands-on learning activity. Can we modify the lab activity to amplify the auditory experience of a learner? We know that the sounds of a tuning fork can be amplified by touching the vibrating tines to an empty aluminum can, which in turn vibrates emitting louder sounds. Can our learner with profound hearing disability hear this? Probably not (Level 0). However, other modifications are possible. By holding onto the handle of a vibrating tuning fork without impeding its vibrations, some individuals can perceive sound if they touch the vibrating tuning fork to their teeth (as the great musical composer Beethoven reportedly did), or to the mastoid bone in front of their ear. In these cases, the sound travels through the bone to the ear.

For all learners, visual vibrations of the tuning fork are difficult to perceive, until the lab is modified, as for example, by touching the tines of a vibrating fork to surface of a container of water and sees the splash (Level 3, accessible with lab modifications). Assuming learners can perceive touch, by gently touching a vibrating tuning fork to the

check, a learner perceives something like a static electricity shock (Level 4, tactile perception fully accessiblity without need for lab modifications).

We included the phrase "personal assistance" in order to include the needs of those students who have orthopedic motor or other impairments that limits their ability to physically handle or manipulate equipment. Returning to our example of the tuning fork activity, a learner who is unable to hold and manipulate a tuning fork and other equipment can be assisted by a peer, the teacher, or an instructional aid. We included "personal assistance" in the sense of a facilitator whose purpose is to enable the learner to engage in the hands-on learning experience.

Our intention is to use the completed LAM matrix to prompt thinking about inclusion of special education students with sensory or orthopedic disabilities. We also found that the LAM discussions on the multi-sensory (multi-modal) learning involved in specific science activities facilitated thinking about accommodations for students with learning disabilities, emotional disturbances and mental retardation. As we thought about LAM accessibility and the types of multi-modal sensory perceptions involved in an activity, we also saw possibilities for improving our instruction and the ways we coach learners involved in a hands-on inquiry experience. During the planning of activities, the LAM matrix provided a way to systematically anticipate various learner needs. While conducting the hands-on activities with learners, the LAM system provided a way to observe and respond to learners as they performed the activities. After the activities were finished, the LAM matrix provided a way to reflect on the learning experiences of specific learners as well as our instructional approaches and responses to the learners.

Relevance to Science Teacher Education

Our work is in progress in testing the LAM system. Preliminary findings from prototype testing of the LA matrix system with teacher candidates in a secondary science methods course point to its potential as a heuristic device to raise questions and reflect on inclusionary science teaching practices. We anticipate further testing and refining the LAM matrix, and in particular the wording of each of the levels of the matrix. Here we can report that during preliminary use of the LAM system, the following questions were generated:

(1) Who is making the judgment call as to whether or not an activity is accessible: the teacher, the student or someone else?

(2) Must all students be fully included in all activities, should some activities be eliminated, or are there instructional alternatives, e.g. offering multiple and varied opportunities to learn a concept or topic?

(3) What methods (e.g. individualized instruction, cooperative learning, or peer tutoring) might be employed to make activities more accessible? and, of course.

(4) What specific modifications might be made to an activity to make it more accessible? (5) What levels of accessibility are acceptable for inclusive science teaching practices?

Although we have seen science methods resource materials with general suggestions for modification for various types of disabilities, to our knowledge we have not seen a similar system for rating an activity or lesson plan in terms of accessibility. Further research is needed to determine the effectiveness of the LAM system in prompting discussion about inclusive practices in terms of process skills, teaching techniques, and assessment strategies. Further research is needed also on the effectiveness of the LAM during the developmental stages of teacher preparation, from

observation-participation to student teaching, and to determine whether the LAM might be useful for special education teachers working with science teachers.

Theoretical Background

Special education students are those identified as requiring special adaptations in order to learn under IDEA 97, the Americans with Disabilities Act, and Section 504 of the Rehabilitation Act of 1973. Further, the Education for All Handicapped Children Act (1975 P. L. 94-142; 1986 P. L. 99-457; reauthorized and retitled to the Individuals with Disabilities Act of 1990 P. L. 101-476; & 1997 P. L. 105-17) provides for free, appropriate education for all children with disabilities, that they be taught in a "least restrictive environment," and that an Individualized Education Plan (IEP) be developed for each identified child. Nationwide, approximately 10-11% of the school age student population is considered disabled, although others may remain undiagnosed (USDOE 1998). Whereas in the past children with disabilities were segregated, today many are now educated with their age-peers in general education classes, a practice sometimes called mainstreaming or inclusive education.

Special education teachers identified science as a subject that is particularly useful for many students with disabilities (Hadary & Cohen, 1978; Mastropieri & Scruggs, 1992; Mastropieri & Scruggs, 1994; Patton, 1993; Scruggs & Mastropieri, 1993). Further, general education teachers (i.e. teachers in nonspecial education classrooms) identified science as the subject area most amenable for mainstreaming students of all disability categories (Atwood & Oldham, 1985).

Related Research

Thus, science classrooms—and, as a result, the science teacher preparation programs—are particularly impacted by inclusion of students with disabilities. Some of the reasons revealed in reports on special education are that science classrooms provide

(1) multisensory approaches implicit in hands-on learning of science concepts (e.g. visual, auditory, tactile, etc); (2) a wide range of instructional techniques to reach learners (e.g. observation, discussion, experimentation; and (3) various types of learning structures (e.g. independent work, cooperative learning, and large group settings) (Kame'enui & Carnine, 1998; Kame'enui & Simmons, 1999; Mastropieri & Scruggs, 1995; Patton, 1995; and Rakes & Choate, 1997. Because science teachers now must learn how to accommodate students with special needs, systemic approaches like the LAM system are needed.

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THE EFFECTS OF AN AFTER-SCHOOL SCIENCE PROGRAM ON MIDDLE SCHOOL FEMALE STUDENTS' ATTITUDES TOWAR SCIENCE, MATHEMATICS AND ENGINEERING

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Introduction

Despite the gains of the last twenty years in the representation of women in scientific fields, their numbers still lag behind their male counterparts. In 1998 women received 13.0% of the Ph.Ds. in engineering, 23.7% in the physical sciences, and 45.5% in the life sciences (National Research Council, 1999). However, this difference increased when the data were desegregated by citizenship. In 1998 Women of American Citizenship earned only 6.2% of the Ph.Ds. in engineering, 12.6% in the physical sciences, and 30.6% in the life sciences.

Although the NRC report did not provide data on the number of Ph.Ds. in science and engineering awarded to minority females, African Americans, Hispanics, and Native Americans combined (female and male) received only 3.2% of the Ph.Ds. in engineering, 3.0% in the physical sciences, and 4.7% in the life sciences. In view of these figures, much talent is being lost which could contribute to the advancement of science and engineering in the U.S. (AAUW, 1992; National Commission on Excellence in Education, 1983).

Theoretical Framework

Researchers have found that until third grade an equal number of boys and girls show interest and feel confident in learning science. By fourth grade, 74% of the girls and 81% of the boys say they like science. These numbers continue to decrease throughout middle school and by eighth grade 64% of the girls compared to 72% of the boys say they like science. By their senior year in high school, only 57% of the girls compared to 74% of the boys show interest in science

(Jones, Mullis, Raizen, Weiss, & Weston, 1992).

Investigators have developed various explanations for the significant decrease in girls' interest in science through their school years. Feminist scholars (Harding, 1986; Keller, 1992; Kelly, 1985; Kleinman, 1998; Salner 1985) postulate that the "male" characteristics of science as currently practiced make its pursuit by girls unattractive. According to Kelly (1985), the portrayal of science as masculine affects a child's gender identification. She contends that science as an intellectual domain is perceived as masculine and that this perception discourages girls from expressing interest in science, from doing well in science, and from continuing to study science.

Others have investigated the role that the family (Huston, 1983; Matyas, 1985; Oakes, 1990; Tracy, 1987) and school (Kahle, Andersen, & Damnjanovic, 1991; Oakes, 1990; Roth, 1996; Shepardson & Pizzini, 1992) play in the socialization of children into gender specific roles. Parents tend to buy more scientific games for boys than for girls, and boys are more likely to play with toys that encourage manipulation, or construction (Oaks, 1990; Tracy, 1987). According to Matyas (1985), boys' toys and games "tend to emphasize relationships between objects, manipulation of objects in space, grouping, and taking apart and rebuilding of objects" (p. 37). These different opportunities for manipulating objects through childhood play appear to be directly related to spatial ability of boys and girls (Matyas, 1985).

Teachers and the classroom environment also contribute to gender socialization (Kahle, Andersen, & Damnjanovic, 1991; Oakes, 1990; Roth, 1996; Shakeshaft, 1995). Although surveys of teacher responses suggest that they hold similar expectations for the success of both boys and girls in science, actual classroom observations uncover differential teacher expectations for boys and girls in science classes starting in elementary school (Kahle, Andersen, &

Damnjanovic, 1991). Boys tend to be encouraged to try again when they fail at something while girls are allowed to give up (Oakes, 1990). In addition, teachers in science classes tend to call on boys more often than on girls, and the questions they ask boys are usually more challenging than those asked of girls (Roth, 1996; Sadker & Sadker, 1986). Teacher questioning is a very important aspect of student learning and is a good indication of the quality of teaching. Good questions focus students' attention and help develop their critical thinking skills by making them express their own ideas, face their own misconceptions, and question evidence (Roth, 1996).

In studies investigating student science experiences, boys report a greater number of actual classroom science experiences and participate in more extracurricular science activities (Kahle, Matyas, & Cho, 1985). Girls have fewer opportunities to experiment, handle less science equipment, and participate less in science-related experiences (Kahle, 1990). These researchers found that boys' greater familiarity with science was related to their greater interest in science-related careers.

Research indicates a strong correlation between attitude towards science and achievement in science (Cannon & Simpson, 1983; Schibeci & Riley, 1986; Weinburgh, 1995). A meta-analysis of the research conducted between 1970 and 1991 indicates that "in all cases a positive attitude results in higher achievement" (Weinburgh, 1995, p.387), and is greatest for low-performance female students. In addition, attitudes toward science predict student selection of future science courses (Farenga & Joyce, 1998) and affect students' aspirations to science careers (Catsambis, 1995). As a result, educators are pressed to find educational strategies that help improve students' attitudes towards science. Some approaches have been successful in developing students' interest in science (particularly females'). Some of these pedagogic approaches include cooperative groups, hands-on activities, role models, and mentors.

Purpose

The purpose of this study was to examine the impact of an after-school science program, which incorporated cooperative learning, hands-on activities, mentoring, and role models on a group of minority female students' attitudes toward science, engineering and mathematics.

Method

Funding

The program was founded by a small grant from the ExxonMobil Education Foundation in collaboration with the Society of Women Engineers. The grant covered the cost of the curriculum development and a part-time program coordinator. One of the local automotive companies covered additional expenses related to supplies, food, and transportation associated with field trips.

Setting and Participants

The program was implemented in a small, urban middle school. The participants were 18 African American, middle school (7^{th} and 8^{th} grades), female students and a group of 7 volunteer, female engineers (5 of them African American) who implemented the program and served as role models and mentors. Each of the mentors worked with a group of 3 students. The mentors were recruited through the local chapter of the Society of Women Engineers.

The biweekly sessions took place from 4:30 to 6:00 P.M. from September 1999 through April 2000 in the classroom of the mathematics teacher. In addition to facilitating the implementation of the program, the mathematics teacher recruited the students and served as the liaison between the implementers of the program and the school's administrators, and students' parents.

Curriculum

The curriculum focused on topics related to the automotive industry and consisted of the following units: Electricity, Magnetism, Gears, Motors, Freezing and Antifreezing, Friction, Speed and Acceleration, and Center of Mass and Gravity. Each of these topics was explored through a variety of hands-on/minds-on activities.

During the activities in these topics, the students made observations, inferences, and predictions, tested their predictions through experimentation, collected data, and built and tested models of car parts. For example, in the "gears" unit, the students started by brainstorming about the concept of "gears" - what they were, examples of items that used gears, and so on. Then the students tested two gears of the same size (a driver and a follower) to determine the direction of the follower in relation to the driver. In the following activities the students added other same size gears and tried to deduct a rule for the direction of the follower gear. Next the students tested combinations of different size gears, while trying to predict the outcome of the different combinations. At the end of this unit, the students were asked to design a toy that used gears.

The students worked in groups of three with one of the mentors as the facilitator. The role of the mentor was to foster discussion among the students, to ensure that all the students in the group participated, and guide them when they had difficulties with some aspect of the activities. In addition, each of the mentors did a demonstration related to their area of expertise. For example, one of the mentors did a demonstration on airbags. This approach helped students observe how a particular concept was applied in the automotive industry, and allowed them to see a female role model in the position of "expert" in her field.

In addition to the after-school sessions, the program included field trips to some of the local automotive engineering plants and museums connected to the automotive industry. During

these trips the students had the opportunity to see how some of the concepts that they had explored through the activities were applied in the design and manufacturing of automobiles.

Evaluation of the Program

According to the director of the program, the main purpose of the program was to foster the girls' interest in science and engineering. Consequently, it was agreed that the evaluation of the program should address only attitudinal change, and not content retention.

To this end, a pre and post-test instrument (4-point Likert-type survey) was developed to measure changes in: (1) students' attitudes towards math, science, and engineering; (2) their misconceptions concerning gender specific careers in science and engineering; and (3) their intentions to pursue a career in science or engineering. The participants were asked to rate each survey item from "strongly agree" (value of 4) to "strongly disagree" (value of 1).

Descriptive statistics were used to identify changes in students' attitudes in the aforementioned areas. Statistical significance was not computed due to the low (N), which made such analysis inadequate. (Of the 18 students who initially joined the program, only 14 completed it). Data were also collected through open-ended interviews with the students and mentors regarding various aspects of the program. These data were analyzed using qualitative methodologies (LeCompte and Preissle, 1993).

Results and Discussion

For each survey item the means and the percentage of students who agreed with each statement were computed for the pre- and post-test. As results in Table 1 indicate, the program had a positive influence on students' attitudes toward science, mathematics and engineering. Although analyses of variance were not conducted because of the small number of participants

(N), the scores on the post-test were higher than those in the pre-test for a number of selected items.

Table 1

Mean and Percentage of Students Agreeing with Selected Items on the Pre- and Post-test

Survey Statement	Average Pre	Average Post	% Agree (Pre)	% Agree (Post)
I like science	2.82	3.00	76.5	85.7
Science is easy for me	2.65	2.86	58.8	78.5
I think science is fun	3.12	3.21	76.5	85.7
Most scientists are men	1.71	1.54	16.8	11.4
Anyone can be a scientist	2.88	3.00	75.7	85.7
I would like to be an engineer some day	2.41	2.86	52.9	78.6
I would like to design the car of the future	2.90	3.00	76.5	85.6
I might study engineering in college	2.82	3.00	76.5	85.7
I like math	3.12	3.89	82.4	92.9
Math is very important for most jobs	3.89	3.93	96.7	100.0
Without good math skills one can not become a scientist or engineer.	2.94	3.29	76.5	78.6
Items on the Post-test Only				
I enjoyed the after school science program		3.50		100.0
I would recommend the program to other girls		3.57		100.0
I liked to work with a mentor		2.93		71.4
Some day I would like to mentor young women		3.43		92.9

All the students also agreed that they enjoyed the program, that they would participate again in a similar program, and that they would recommend the program to other girls. In addition, when asked "What did you enjoy most in the after school program?" all the girls answered the hands-on activities and field trips. One of them responded, "I enjoyed building models, car parts, and paper works." Another one added "Doing activities because they were very educational and fun." Still another answered, "when we went on field trips we had a lot of fun and we got to meet new people." These responses were common among the students' comments. The response of one of the girls, however, reflected a greater awareness about some of the gender issues that the program was trying to address. She pointed out that she had "liked when we made things, because it just goes to show you girls can do the same as boys."

These results confirm previous ones in which increased experiences with science such as performing experiments lead to positive attitudes toward science classes and science related careers (Bartsch, Snow, & Bell, 1998; Lee-Pearce, Plowman, & Touchstone, 1998; Travis, 1993). Hands-on activities have shown to significantly increase student learning in science, mathematics, and writing (Sutman, Bruce, May, McConaghy, & Nolt, 1997). Hands-on activities have also shown to increase student problem-solving skills, self-confidence, and improve their attitudes toward science and science related careers (Bartsch, Snow, & Bell, 1998; Lee-Pearce, Plowman, & Touchstone, 1998; Tyler-Wood, Cass, & Potter, 1997).

Feedback from the students' mathematics teacher also indicated that the program positively influenced the students in other ways. According to the teacher the attitude of some students had improved since the onset of the program. She mentioned particular students whose participation in mathematics class has increased. According to her, these students "participate in class and encourage others to participate. They talk to me openly and freely about their problems

with math, other students, and 'life'." She made reference to specific students whose past behavior in class had been disrupting. According to her, "they have stopped their rude outbursts in class."

The positive impact of the program on students' attitudes toward mathematics might have been due, in part, to the teacher's involvement in the program. The after-school sessions took place in the mathematics teacher's classroom. She played an active role in the implementation of the program and was present at every session. Thus, the students had the opportunity to view their mathematics teacher and develop a relationship with her outside the constraints of the regular mathematics class. Furthermore, because most of the science activities involved mathematics, students had the opportunity of experiencing mathematics in the context of its applications in science and engineering (Lee-Pearce, Plowman, & Touchstone, 1998; Rohrer & Welsch, 1998). For example, when studying the concepts of velocity and acceleration, the students had to compute the velocity and acceleration using a model vehicle.

Impact of the Program on the Mentors

Research on mentoring indicates that both mentor and protégé benefit from the relationship (Fagenson, 1989; Hall & Sandler, 1983; Healy & Welchert, 1990). The mentor serves as a role model and provides knowledge, advice, acceptance, and confirmation to the protégé (Fagenson, 1989). On the other hand, the mentor benefits from the satisfaction of making a positive impact on another person and often receives admiration, respect, and gratitude from the protégé (Hall & Sandler, 1983; Healy & Welchert, 1990).

The results of this study indicate that the mentors perceived themselves as role models and viewed their involvement in the program as an opportunity to make a positive impact on the girls' attitudes toward engineering. According to one of them the girls in her group looked up to

her "as their big sister, as they often called [her]." When asked about the strengths of the program one of the mentors answered that, ". . . we really can make an impact on these girls' lives and possibly interest many of them in the sciences and engineering." Another one commented that the program "helped the girls learn the importance of team work to complete a task, especially on the final project. They seemed to stay interested in the various topics and experiments, asking a lot of good questions in our post-discussions." These comments indicate that the mentors played an important role in the socialization of the girls into the field of engineering (Fagenson, 1989; Turner & Thompson, 1993).

Some researchers contend that the lack of role models and mentors in science and engineering is a contributing factor to females' lack of interest in science and science-related careers (Matyas, 1985; Marlow & Marlow, 1996). Although research indicates that a mentor or role model does not necessarily need to be of the same race or sex as the protégé, seeing others of the same sex and/or race in positions of power and expertise helps affirm one's career aspirations (Astin & Astin, 1993; Janes, 1997; Kegel-Flom, 1995).

Conclusions and Limitations of the Program

The results of this study add to the existing body of knowledge on the impact that enrichment science programs, that employ a variety of pedagogical strategies such as cooperative learning, inquiry and mentoring, can have in narrowing the gender gap in science, mathematics, and engineering.

For instance, cooperative learning groups have shown to be particularly successful with females who tend to dislike the competitive aspects of science (Peltz, 1990). Cooperative learning has been found to facilitate student learning in science and improve their attitudes toward science (Bianchini, Holthuis, & Nielsen, 1995; Cannon & Scharmann, 1996; Chang &

Mao, 1999; Kahle and Rennie, 1993).

However, even though this program's goals were commendable and it exhibited important characteristics recommend by research (hands-on activities, cooperative learning, role models, and mentors), its impact was limited by a number of shortcomings related to its implementation: Scheduling and the mentors' lack of pedagogical knowledge.

Scheduling

In order to meet the mentors' working schedule, it was decided that the sessions would take place every other week, after school, and be 1.5 hrs. long. However, after being in school for a full day, some students had difficulty committing themselves to spend an additional hour and a half in school. Although incentives such as pizza and attendance awards were used, enrollment in the program was low (18) and attendance to the program by some students was sporadic. In addition, the two-week interval between sessions limited knowledge transfer from one session to the next, particularly when students needed to apply concepts learned in previous sessions.

The amount of time allocated to each session (1.5 hrs.) was also not adequate to properly cover some of the day's science activities, which usually involved making observations, inferences, predictions, testing predictions (i.e. collecting data), and often included a presentation by one of the mentors.

Thus, programs such as this one are best implemented weekly, on Saturday's mornings, in 2.5-3.0 hrs. blocks of time. This type of scheduling facilitates content coverage and transfer, and has the potential to increase student attendance and retention.

Mentors' Pedagogical Knowledge

As previously pointed out, the program focused on science activities related to automotive engineering and was implemented by a group of women engineers. It was hoped that the combination of engineering related activities and engineer role models would have a positive impact on students' attitudes toward engineering-related careers. However, it was somewhat surprising to find that only 71.4% of the students agreed with the statement "I liked to work with the mentor" (see Table 1).

Although the mentors were practicing engineers with expertise in various areas of engineering (mechanical, chemical, electrical), some of them were not familiar with the pedagogical approaches used in the program. Their comments indicated that they had limited understanding of cooperative learning and/or inquiry and used a traditional approach of "telling" instead of guiding the students through the activities as facilitators. The traditional educational experiences that some of the mentors had experienced themselves as students might have contributed to the way in which they perceived their role in the implementation of the program. Some of them were visibly uncomfortable with the "exploratory" nature of some of the activities and had difficulty involving all the students in their group as the following comment indicates:

> The experiments in which the students were building something (circuits, the plane model, etc.) were difficult because only one person could work on the activity at a time. If I'm working with 3 students, it is hard to keep the other 2 occupied, interested and involved in the activity.

In addition, although all the mentors were given a handbook with all the activities, objectives for each, and advice on how to involve students through questioning, some of the mentors did not examine the day's activities until the beginning of the session. As a result, they

were often unprepared to answer student questions and appropriately guide them through the activities.

These issues were reflected in some of the students' answers to the question "What did you enjoy least in the program?" According to one of the students, "The thing I least enjoyed about the program was that our mentor was not always there, attentive and sure of what she was doing." Another student responded, "My mentor had an attitude problem and some of the other mentors did too." Furthermore, when asked, "What things (if any) should be changed in the program?" one of the students responded, "Make sure all the mentors know what they are doing, so if we have questions they can help us."

These results indicate that to maximize the success of programs such as this one, mentors and others involved in the implementation of the program must become familiar with the pedagogical approaches used in the delivery of the program. This might require training sessions for mentors and other facilitators as well as follow-up sessions.

Lastly, the lack of data on increased student participation and achievement in science was one of the limitations of the program's evaluation. As previously pointed out, the program director was mainly interested in measuring the impact of the program on students' attitudes toward science and engineering. She felt that if achievement were part of the evaluation, the mentors might place too much emphasis on content coverage, thus discouraging some students from participating in the program.

Some researchers (Cannon & Simpson, 1983; Schibeci & Riley, 1986; Weinburgh, 1995) have found a positive relationship between student attitudes toward science and their achievement in science. Others have found that attitudes toward science predict student selection of future science courses (Farenga & Joyce, 1998), and affect students' aspirations to science

careers (Catsambis, 1995). However, since data on achievement and participation were not collected, conclusions regarding the program's impact in these areas cannot be made.

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SCIENCE AND MATHEMATICS PROFESSIONAL DEVELOPMENT AT A LIBERAL ARTS UNIVERSITY: EFFECTS ON CONTENT KNOWLEDGE, TEACHER CONFIDENCE AND STRATEGIES, AND STUDENT ACHIEVEMENT

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Ultimately if we are to see successful mathematics and science education reform, it is classroom teachers who will have the most influence. They will be the ones to implement the national standards and have the most direct impact on student achievement (Bybee, 1993; Cohen & Hill, 1998). One of the major reform recommendations is to enhance the science and mathematics knowledge of the classroom teacher because many teachers lack the necessary content information in these areas (AAAS, 1993; Carre, 1993; Kruger, Summers, & Palacio, 1990). Many studies indicate that teachers must possess the content knowledge of a subject to have an impact on student learning (Anderson, 1989; Grossman, Wilson, & Shulman, 1989; Hashweh, 1987; Shulman, 1986;). Furthermore, findings show that teachers must comprehend the material before they can transform that knowledge, called pedagogy-content knowledge, into a form that can be taught (Happs, 1987; McDiarmid, Ball, & Anderson, 1989; National Center for Improving Science Education, 1989; Shulman, 1987; Tobin, 1987; Tobin & Garnett, 1988;). Compounding the lack of science and mathematics content knowledge is what Bell & Gilbert (1996) refer to as 'progression'(p. 2). The progression of curriculum refers to the fact that what knowledge is taught and students are expected to learn is continuously increasing. This void of content knowledge has been recognized as a critical focus if classroom teaching and subsequent student learning is going to improve (Hashweh, 1987; Leinhardt & Smith, 1985; Shulman, 1986; Tamir, 1991). Training educators in specific content areas is essential and most teachers acquire the bulk of their content knowledge in their high school and undergraduate studies. In the state of

Ohio, new middle school licensure standards require a concentration in two subject areas and this will alleviate some of the deficiency in content knowledge. To that end, the mathematics and sciences faculty at Xavier University have collaborated with teacher educators to develop courses to incorporate national standards and model appropriate teaching strategies. For example, students use manipulatives to learn mathematical concepts or use an inquiry approach to learn about scientific concepts. Shulman (1990) stresses that the role that university courses play in the teaching process cannot be undermined and those courses greatly affect how a teacher teaches.

These two improvements help alleviate the problem for Xavier undergraduate, preservice teachers, but what about the educators who are currently teaching? How does the university assist them in acquiring additional content knowledge? The educational faculty believes the answer is professional development. Gess-Newsome & Lederman (1995) reported that teachers subject information was most influenced by their own teaching experiences and their college-level content courses. Professional development is much needed because many teachers have inadequate experiences in their own science and mathematics learning and their exposure to effective teaching strategies in theses areas is almost nil (NRC, 1996; NCTM, 1991).

In the past few years, many studies and documents have provided professional development procedures to help science and mathematics classroom teachers. Appropriate components and strategies to achieve specific goals through professional development have been identified (Haney & Lumpe, 1995; Loucks-Horsley, Stiles, & Hewson, 1996; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Mundy, Spector, Loucks-Horsley, & Morrison, 1999; Radford, 1998). Smith and Neale (1989) suggested professional development for teachers address specific science content rather than broad topics so teachers can build their knowledge. The professional development consortiums formed after the release of the TIMSS results (NCES, 1999) have

focused on connecting a district's curriculum to the subject matter content knowledge needed by the teachers (Dunson, 2000). The impact of content knowledge on how a teacher teaches is profound. How much a teacher knows about a specific topic determines the strategies he or she chooses (Carlsen, 1991; Gess-Newsome & Lederman, 1995; Tomanek, 1992). Improvement in this area is much needed if teachers are crucial in bringing about changes in the schools. Professional development is essential if we want to improve student achievement and we want the science and mathematics education standards to be implemented by capable teachers.

The beliefs teachers have about a subject area is another critical consideration in determining whether mathematics and science content will be taught and will be taught according to standard guidelines. The literature details the strong relationship between teacher beliefs, their teaching behaviors, and student learning (Brickhouse, 1990; Gess-Newman & Lederman, 1995). Teachers' beliefs about a subject have a great influence on what they teach and whether or not they implement the standards in their classrooms and teaching (Grossman, et. al., 1989; Haney, Czerniak, & Lumpe, 1996; Lumpe, Haney, & Czerniak, 1998; Tobin, Tippins, & Gallard, 1994). Anderson, R., Anderson, B., Varanka, et al. (1992) stress that if reforms are going to move forward than teachers' beliefs about the subject matter must change. Effective professional development is one way to change teachers' beliefs (Haney & Lumpe, 1995).

This study takes into account the reform recommendations for mathematics and science, the research on content knowledge and teacher beliefs, and components for effective professional development. It examines (a) Xavier University's professional development program with middle school science and mathematics teachers from a large urban district, (b) its effects on teachers' content knowledge, (c) the teachers' confidence in teaching these subjects, and (d) the impact on classrooms and students.

History

Over the last four summers, Xavier University's Center for Excellence in Education has offered the Mathematics and Science Institute for urban, K-12 teachers. The institute focuses on content courses in mathematics and science. Xavier University has funded the institute jointly with several agencies: OSI Discovery: Ohio's Systemic Reform of Science and Mathematics Education and the NSF Urban Initiative for Cincinnati Public Schools. Collaboration among Xavier University faculty in the mathematics, sciences, and education departments, and with school administrators and classroom teachers has created a successful program in which science and mathematics content courses are connected to meet the needs of the district teachers. The foundation for the courses are based on the *Science - Ohio's Model Competency-Based Program* (Ohio Department of Education, 1994), *Ohio Model Competency-Based Mathematics Program* (Ohio Department of Education, 1990), the *National Science Education Standards* (NRC, 1996), the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), and the Cincinnati Public School Courses of Study and Promotion Standards (1995).

The teachers who participate in the Mathematics and Science Institute teach in a large, urban district with a population of 44,000 students of which 70% are African-American, 25% Caucasian, and 5% other minorities. The teacher population according to the 1997-98 Cincinnati Public School Annual Performance Report gives the district demographics as 76.8% female and 23.2% male, 70.4% Caucasian, 27.2% African American, and 2.4% other minorities.

During the last four years, 330 K-12 teachers have taken a total of 911 courses in the Xavier University Mathematics and Science summer institutes. Each summer specific grade levels are targeted and ten, different weeklong courses are offered: five in mathematics and five in science. All courses are team taught by a mathematics or science professor and a teacher educator or classroom teacher. During the first two years of the institute a follow-up day in early

winter brought teachers back together to share their lessons developed from the summer institutes. Unfortunately, during the last two institutes follow-up days were precluded by the lack of funding. For a small, liberal arts university with an undergraduate population of 3500 students, the number of teachers attending the institute was significant.

Data collected during the first two years consisted of course evaluations and teachers' narrative inputs on the strengths and weaknesses of the individual courses. Although this information helped faculty fine tune and adjust their classes to best meet the needs of the teacher, it did not provide further information on the courses impact on the teachers' teaching and student achievement. During the third summer, the researcher began to collect data to determine the outcomes of the institute courses.

The focus of this study is on the Middle School Science and Mathematics Institute offered during the past summer. Seventy, urban middle school teachers of grades 4-9 took an average of three courses each, totaling 214 weeklong courses taken altogether. The following courses were offered: Chemistry and Society, Nature of Science, Plants in the Middle School Classroom, Earth Science for Middle Grades, Animals for Middle Grades, Adventures in Data and Probability, Topics in Discrete Mathematics, Patterns and Number Sense for Middle Grades, Algebra and Intermediate Problem Solving, Measurement and Geometry.

The courses are based on the constructivist model of teaching mathematics and science whereby teachers build their current knowledge and understandings by involvement in hands-on, concrete lessons and the investigation of concepts (Vygotsky 1962, von Glasersfeld, 1989, 1992). The professional development designed by the faculty is based on the widely accepted standard that teachers will learn more effectively if they are involved in their own learning and reflect on it. (NRC, 1996). Faculty did not teach these courses in a traditional method, but rather they engaged the teachers by posing questions and problems, involving them in activities, and

using mathematics manipulatives and science experiments to teach the content. In other words, the faculty modeled appropriate teaching strategies as recommended by the standards (NRC, 1996; NCTM, 1989).

As more information on effective professional development in mathematics and science became available, these strategies were incorporated into the Mathematics and Science Institute (ENC, 1999; Loucks-Horsley et al., 1998, Mundy et al., 1999). Components of the institute included, working collaboratively, considering teachers' needs and concerns, actively involving teachers in their own learning and understanding, and focusing on depth of content material vs. breadth. In addition, making connections between content knowledge, classroom needs, teaching strategies, and lessons were utilized (Bell & Gilbert, 1996; ENC, 1999; Loucks-Horsley et al., 1998). Based on our own experiences with professional development and information in the literature (O'Brien, 1992), the faculty also included practical considerations concerning time, incentives, specific needs of grades levels and subject matter, and individual attention.

Research Questions

Using professional development and teacher beliefs research and history as a foundation for the Science and Mathematics Institute, data were collected to determine the effectiveness of the institute and the impact on teachers and classrooms. The following research questions were asked: (a) What effects did the courses have on the middle school teachers' science and mathematics content knowledge base and confidence levels of teaching different areas of science and mathematics? (b) What impact did the courses have on the teacher's teaching strategies and student achievement?

Methodology

Middle school teachers (grades 4-9) were notified of the course offerings through brochures and announcements sent by the district administration office. There are approximately

165 middle school mathematics and science teachers in grades 7-9 and approximately 280 math and science teachers in grades 4-6. Approximate numbers of teachers are given because the schools are organized differently. Some schools have self-contained classrooms, where others are departmentalized.

Seventy teachers enrolled in institute courses. The participants were 80% female (*n*=56), 20% male (*n*=14), 75% Caucasian, 20% African American and 6% other minorities. Based on collected interview data (*n*=34) the number of years teaching experience ranged from 2 – 29 years with a mean of 12.8 years. Average years teaching mathematics was 9.4 years and science was 12.3 years. Science teachers had an average of 28.7 semester hours of previous science content courses, whereby the math teachers had an average of 29.3 semester hours of mathematics courses. The average number of minutes they spent each week teaching science was 243 and 265 minutes for mathematics.

Professional Development Description

Teachers could choose among five science courses and five mathematics courses. Each weeklong course involved 30 classroom contact hours. Sixty-seven percent (*n*=47) of the teachers took three or more courses and focused on either mathematics or science. The intent of the courses were to broaden the teachers' science and/or mathematics content knowledge and, at the same time, demonstrate how mathematics and science content can be taught without lectures or rote memorization. The courses addressed national, state, and district standards and connected them to the science and mathematics content being taught. Many of the activities had a real world context so that the teachers could see the application of the science and mathematics concepts but more importantly they could transfer this learning into their own middle school classrooms. Middle school students have started to develop life aspirations, and are beginning to see themselves applying the information they are learning in school (Hanley-Maxwell & Collet-

Klingenberg, 1997). Making these connections was important because often teachers are unable to transfer their content knowledge to the classroom.

The content of each course was not designed to be a comprehensive curriculum of all the concepts that a teacher would need to know; rather, it was an in-depth review of a few topics. The content was taught at the college level so that teachers developed a greater understanding of the concepts which would enable them to design higher level questions, respond to students appropriately, and develop different teaching episodes in their own classrooms.

With this framework in mind, the professors approached the content for their courses in non-traditional ways. The courses were all taught using a hands-on, interactive type approach. For example in the mathematics course that focused on concepts in probability and data analysis, teachers and faculty met at a large local cemetery where participants were assigned to four groups of six or seven. Each was given a worksheet and asked to roam through the cemetery, finding thirty gravestones, ten for the individuals who died before 1900, ten for those whose deaths occurred between 1900 but before 1950, and ten with deaths since 1950. The teachers recorded the year of birth and death for each gravestone. The instructions caused the samples to be as random as possible. For example the participants were to go in different directions and no more than one stone was to be observed from any family group. The groups then had at least sixty pieces of data from each of the time periods. Data were collected in the morning, then the groups returned to campus to combine their information and create reports using the data. The groups were assigned methods for analysis of the data.

- Group A found the mean, median, mode, and midrange for the ages at death for each of the death-year groups,
- Group B made a scatterplot with the year of death on the horizontal axis and age on the vertical,

- Group C made histograms and stem-and-leaf-displays for each of the three categories,
- Group D made box plots for each of the three death-birthdate categories.

All were asked to report on the question, "Does this indicate that people are living longer?" Each group prepared a report answering this question both in written form and as a presentation. All members of the group were required to have a role in the oral presentation. Groups were encouraged to employ methods such as multimedia presentation software to present data, the internet to perform searches for documents that would support their position, and spreadsheet software or graphing calculators to do the analysis. Group presentations were given during the afternoon.

It must be noted the Arts and Sciences faculty worked with the science and mathematics teacher educators to learn about appropriate teaching strategies and needs of the K-12 teachers. Many of the faculty were already using (a) collaborative groups, (b) approaches that were inquiry based, and (c) manipulatives and hands-on materials rather than a lecture approach. The institute could not have been implemented without their efforts and different approaches.

In each course, different materials were provided so teachers were able to recreate similar lessons back in their own classrooms. The teachers were given extensive handouts of activities, experiments, resources, and standards. The course materials included items teachers could purchase at grocery, hardware, or pet stores. By using these materials, teachers realized that they did not need sophisticated equipment to learn and teach these subjects. In addition, urban districts have minimal budgets to purchase equipment so the types of items we used were inexpensive to purchase. Middle school supplemental texts that focused on specific topics and concepts addressed in the courses were purchased for the teachers. The courses also incorporated field trips to community resources such as the Natural History Museum to study local geology; the Cincinnati Observatory to learn about telescopes and planetary motion; the Krohn Arboretum

to study plant diversity; and a county park to collect fossils.

Technology was utilized and integrated into the courses. The teachers used technologies such as graphing calculators, spreadsheets, databases, and Internet resources to accomplish goals of the courses. Professors used a variety of assessments in their courses such as daily journals with focus questions, problem solving assignments, development of middle school lesson plans which incorporated concepts learned during the courses, daily concept maps, and peer teaching of middle school mathematics and science lessons. The facilitators believed strongly that teachers should be treated as professionals and receive compensation for their time and effort. To support this notion, each teacher received $100 worth of materials and books, one semester credit hour, and $100 stipend for every course.

Research Design

Data were collected using the following: written content tests, individual interviews, and classroom observations. Teachers were given a science or mathematics content pretest at the beginning of classes and a posttest upon completion of all their courses. The 20 item instruments were designed to cover the concepts from all the science or math courses (Tables 1-2). The test consisted of multiple choice and written response questions and was developed by the researcher.

Table 1

Sample items from pre- and post-mathematics test

1. If a + b = 25, and a-b + 17, what is the value of a? A. 4, B. 8, C. 21, D. 42.
2. A drawer contains 6 red socks and 4 blue socks. If a sock is chosen at random and not replaced, then a second sock is chosen, what is the probability that both socks are blue?
3. What happens to the ratio of two consecutive numbers from the Fibonacci Sequence as the numbers increase? 1/1, 2/1, 3/2, 5/3, 8/5...

Table 2

Sample items from pre- and post-science test

1. Given a diagram of the moon's revolution around the earth, students are asked the following: If viewed from earth, which position would represent a full moon? A. Position A, B. Position C, C. Position E, D. Position G

2. Before a campfire is completely burned out, you ask your friend to get some more firewood. Jokingly, your friend asks you why you cannot burn the ashes. Which of the following explains why you cannot burn the ashes? A. The stored chemical energy of the driftwood has already been released. B. The kinetic energy of the wood has already been changed to chemical energy. C. The volume of the ashes is less than the volume of the wood burned. D. The temperature of the ashes in the fire is too high.

3. Given a description of an experiment, students are asked: The results of the experiments provided the greatest support for which of the following hypotheses? A. Water is necessary for controlling burning. B. Plants emit a gas that supports burning. C. Light is necessary for plant growth. D. Plants cannot grow in an airtight environment.

Not only did the researcher want to determine if the courses improved the content knowledge of the teachers, but the professors also wanted to determine if the teachers gained content knowledge when university mathematics and science courses were taught in a nontraditional way. The constructs of the questions on the pretests and posttests were connected to the content taught in each course. Mathematics and science professors examined the tests and provided input to further determine the validity.

Classroom observations of science and mathematics teachers were completed during the spring prior to the summer courses. In the fall after the courses were completed, these same teachers were observed again. The observations targeted teaching strategies, types of questions, science or mathematics content areas, classrooms interactions and room layouts.

Thirty nine percent (*n*=27) of the participating teachers were interviewed prior to the courses. Post interviews were conducted with the same teachers after the completion of the

subsequent school year. Each interview took approximately twenty minutes and was conducted via telephone by a graduate student. Included in this interview were items related to teaching experience in mathematics and science, confidence levels in teaching different areas of math and science, teaching strategies, and student achievement. To determine the internal consistency on questions related to confidence, the Cronbach alpha coefficiency was employed. The Cronbach alpha reliability for the science confidence test was .57 and the mathematics confidence was .69. The questions developed for the confidence levels for teaching various science or mathematics content were based on the research of beliefs and their effects on teaching science and math (Haney & Lumpe, 1995; Haney, Czerniak, & Lumpe, 1996; Lumpe, Haney, & Czerniak, 1998). For example a question on the pre/post interview asked teachers to identify their levels of confidence in teaching specific content such as earth science. Teachers responded very confident, confident, or not confident. On the post interview, additional questions pertaining to application of the new content knowledge and impact on teachers and students were asked. Anecdotal information on the effectiveness of the institute also was gathered during the post interview.

Results

A paired *t*-test was conducted on the science and mathematics content pretest and posttest. The research question results indicated the institute's courses improved middle school teachers' science and mathematics content knowledge. (See Table 3).

Table 3

Paired *t*-test results for Science and Mathematics Content Knowledge

Measure	*n*	Significant
Mathematics Content	32	*

Science Content	32	*

$*p \leq .05$

The second research question analysis used paired *t*-tests to determine if the confidence levels in teaching particular areas of science or mathematics changed as a outcome of the summer institute. The tests showed varied results. The results for mathematics indicated that teaching functions was the only confidence level that had increased significantly. All confidence levels in teaching different areas of science had significantly increased except for the nature of science (see Table 4 below). Upon further examination of the response frequencies on the pre and post interviews, the mathematics teachers consistently responded their confidence levels for different areas of math were confident or very confident. However the teachers' confidence levels in teaching science increased as a result of the courses. The levels went from not confident to very confident relative to the different science topics (see Table 4).

Table 4

<u>Paired *t*-test Results of Confidence in Teaching Science and Mathematics</u>

Response Options: Very Confident, Confident, Not Confident

Paired *t*-test Confidence Levels for teaching science	*n*=16 Significant	Paired *t*-test Confidence Levels for teaching math	*n*=12
Confidence in teaching	*	Confidence in teaching	NS
Science overall	*	Math overall	NS
Earth Science	*	Algebra	NS
Plants	*	Geometry	NS
Chemistry	*	Discrete Math	NS
Physical science	*	Data Analysis	NS

Animals	*	Patterns	NS
Nature of Science	NS	Functions	*

*$p<.05$

The third research question focused on the impact the courses had on a teacher's teaching strategies and student achievement. Overall, the teachers' responses showed very positive results. The courses influenced what and how teachers taught science and mathematics. They felt more confident in using hands-on materials and different teaching strategies and the additional content knowledge they learned was transferred to the middle school classrooms. Most importantly, the teachers indicated that the students understood the mathematics and science concepts better and student achievement in these areas increased. The results are given in Table 5.

Table 5

Impact of Content Courses on Teachers, Classrooms, and Students

Post Interview results (n= 27)

Questions	Responses	
The courses I took last summer at XU changed the way I taught.	Strongly Disagree	3.7%
	Disagree	11.1%
	Neutral	22.2%
	Agree	40.7%
	Strongly Agree	22.2%
I am able to teach science (math) concepts better as a result of the XU courses.	Neutral	14.8%
	Agree	48.1%

	Strongly Agree	37.0%
I feel more confident using manipulatives and other hands-on types of teaching strategies as a result of the XU courses.	Disagree	3.7%
	Neutral	14.8%
	Agree	48.1%
	Strongly Agree	33.3 %
I incorporated the concepts and ideas I learned in the XU courses in to my science (math) lessons this past year.	Neutral	3.7 %
	Agree	40.7%
	Strongly Agree	55.6%
As a result of the XU courses, my students had a better understanding of science (math) concepts.	Disagree	3.7%
	Neutral	14.8%
	Agree	40.7%
	Strongly Agree	40.7%
What impact do you think the XU courses had on your students' science (math) achievement?	Stayed the same	22.2%
	Increased	77.8%

Classroom observations were made before the summer institute and during the following fall to obtain a snapshot of what occurred in the classrooms. These observations verified the results of the survey.

Discussion

The professional development model used in the Science and Mathematics Institute proved to be a successful one for our university. The research on professional development strategies and the national standards guidelines provided the foundation for teaching science and

mathematics content. Through this study, the researcher identified key components to consider when planning similar courses for teachers.

1. Instructors model teaching strategies suggested by the national standards and literature. The collaboration of the scientists, mathematicians, teacher educators, and classroom teacher created a strong integration of subject matter, district curriculum components, and teaching strategies.

2. A well-established relationship of trust and collegiality between education faculty and mathematics and sciences faculty is necessary to implement this type of program.

3. Arts and science faculty must know and understand the science and mathematics national standards and district courses of study.

4. Teacher educators act as consultants to the arts and science faculty to assist them in constructivist teaching approaches and concepts.

5. Collaboration between arts and science faculty and teacher education faculty to discuss and work through the components of the professional development program should begin early. Allowing ample time to develop the working relationship is necessary.

6. Time is a critical factor for teachers. They often lack the time to find materials and resources (Mundry, Spector, Loucks-Horsley, & Morrison, 2000). Provide these types of things to teachers so they do not have to do it on their own.

7. Content focus is directed at the district's specific course of study and the needs of the teachers. Communicate with district administrators and teachers to identify content areas.

8. Team teaching and collaboration between scientists, mathematicians, teacher educators, and classroom teachers enhance the courses greatly by tapping into each individual's expert knowledge.

9. The partnering of a classroom teacher or teacher educator with a scientist or mathematician provides real classroom connections to the courses.

10. Scientific and mathematical content is taught in a real world approach. Specific activities and lessons are connected to everyday life.

11. Direct connections are made between the middle school classrooms and the content taught in the courses.

12. Teachers develop and share lessons based on what they have learned in the content courses.

13. Providing incentives such as stipends, credit hours, and materials were motivating factors for the teachers. Materials and resources allow teachers to conduct activities in their own classrooms.

14. Small classes (approximately 18-22) allow the teachers to participate and interact with the instructors more. More personal attention is given to individuals.

15. The results of the class assessments show that when the instructors model a constructivist approach by using manipulatives and hands-on materials, the middle school teachers develop a better understanding of the concepts being taught.

16. Different types of assessments provide models for teachers to use in their own classrooms.

Several areas for future research and institute modifications were recognized as a result of the study.

1. Focusing on the specific content most needed by the teachers is sometimes hit or miss. In addition to analyzing the district standards and informal questioning with teachers, it may be more appropriate to use a formal questionnaire to determine teachers' needs.

2. More observations of the same teachers are needed to provide thorough information of teaching strategies, classroom interactions and happenings.

3. Even though state license in Ohio for middle childhood is grades 4-9, the broad age-range was troublesome for the instructors because the higher grade level teachers most often had a much stronger background in science and mathematics than grade 4-6 teachers.

4. Obtaining more information on student achievement other than teachers' assessment would give a clearer picture on the impact of the Xavier University courses. The State of Ohio's standardized proficiency tests may be one area to consider.

5. Lack of follow-up days during the school year precluded necessary time for sharing of lessons, feedback, and further collaboration

Other important benefits of the institute were the effects on the university's faculty. The institute provided a venue for teacher education faculty and arts and sciences faculty to work together. The courses gave them a better awareness of how mathematics and science education and the mathematics and science content courses were closely related. The role that each group plays in improving science and mathematics education is more obvious when such a working relationship exists. The strategies the arts and sciences faculty learned and used in the institute carried over to their regular undergraduate courses. And the teacher educators profited because they connected educational concepts to experiments and content taught in mathematics and science courses. The bottom line was a better education for future teachers. Overall, both

groups learned how our partnership benefited our professional relationship, our courses, our students, and the teachers in our community.

Specifically, the education department gained a greater pool of science and mathematics teachers for field experiences. As the classroom teachers learned more information about content, strategies, and standards, they became better cooperating teachers for Xavier's preservice teachers.

The ultimate goal of any professional development program is that the knowledge and training are utilized in teachers' classrooms. The findings indicate this was the result of the Science and Mathematics Institute. The middle school teachers used the new content knowledge, teaching strategies, and materials. Most importantly, the courses increased student achievement. The interview data indicated that as result of the institute courses, the majority of teachers (81.4%, n=27) thought their students had a better understanding of math or science concepts. Furthermore, the majority of teachers (77.8%, n=27) thought the Xavier University courses increased their students' achievement in math and science.

The Science and Mathematics Institute transformed several areas: (a) The courses improved the science and mathematics content knowledge of teachers. (b) The institute gave educators what they wanted and needed and often gave them a greater confidence in teaching specific areas. (c) The standards approach gave teachers new ideas, materials, and teaching strategies that were utilized in their classrooms. (d) The institute had a positive impact on student achievement.

In conclusion, integrating the standards, teacher and district needs, and constructivist teaching strategies to teach new content knowledge contributed to the success of the courses. The considerations mentioned in the discussion section can furnish guidelines for enhancing the science or mathematics content knowledge of teachers. Certainly, a university must examine

their resources, their faculty, and the needs of their local school districts to construct an appropriate professional development program. Small colleges and universities can affect the mathematics and science teaching profession greatly. Providing a standards-based professional development program that incorporates the components detailed here enables a university to assist their community of educators in improving mathematics and science education.

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SEXUALITY HAS A PLACE IN THE SCIENCE CLASSROOM

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During my 13 years as a college biology teacher, I have spent a great deal of time considering how to best incorporate sexuality in my courses. Sexuality is a significant part of science, through the aspects of physiology, psychology, behaviour and the evolutionary sciences. For this paper, I am offering my anatomy and physiology course as one model of how future teachers might engage the complexity and diversity of human sexuality within a rigorous science curriculum.

I teach anatomy and physiology to college students, primarily those in health science majors. My students are mostly majoring in athletic training, nursing, and physical therapy. One of my concerns as a teacher is that the students find relevance, even in the more abstract topics. Women, minorities, and other 'outsiders' are often not comfortable with reductionist scientific topics. (Rennie & Parker, 1998; Costa, 1995; Rosser, 1989). Providing context to these topics is a way to draw students into understanding topics which are very abstract when presented in the usual 'stand alone' manner. (Brickhouse, 1994; Costa, 1995; Gallard, 1992).

Another concern is that my students do not feel excluded by the course (as I did growing up, by the absence of active women in the media). Therefor, if I am going to discuss sexuality, I should not exclude gay, lesbian, bisexual and transgender (GBLT) sexuality from my discussion.

A third concern is that my students are going into the helping and health professions, and as such should be comfortable with discussions of sexuality, and with all of the various topics that entails. They will encounter GBLT students, patients, and clients. An awareness of sexuality is important in the health fields so as to provide a safe environment for treatment (Morgan, 1999; Schacter, Stalker & Teram, 1999; Velesquez, 1998), to provide information for the client or patient when requested (Barnes, 1999; Morgan, 1999; Hunt & Pujol, 1994), and to help with rehabilitation or education regarding sexuality after an illness or injury (Gondek, 1999; Brown, 1998; Gamel, Davis & Hengeveld, 1993) . In my course on Anatomy and Physiology, the majority of my students will have these sorts of responsibilities. I consider it part of my job to start acculturating my students to the reality that their future clients will also be sexual beings. Part of this process is gaining an awareness of the true variety in gender and in sexualities which these clients may represent.

Future science teachers are also planning to work in a helping profession. As such, they too need a sophisticated understanding of the complexities in human sexuality. At a minimum, they need to consider how their planned curriculum will interact with the sexual culture of the students present in their classroom.

Sexuality as a source of relevance

Given that most students are interested in the topic, sexuality is one way that a science teacher can anchor an abstract topic into context. Context which a student can relate with his or her own life will help the student create 'connected knowledge'. The creation of connected knowledge involves finding the personal importance and meaning

related to abstract ideas. This is one of the ideals in feminist education, and now also in multicultural education (Costa, 1995; Brickhouse, 1994; Belenky, Clinchy, Golberger & Tarule, 1986).

One example of a typical abstract topic is the specialized cell division of meiosis. Meiosis leads to chromosomal sex. In addition to Down's syndrome, meiotic error can lead to Turner's syndrome. Turner's syndrome is a 45 XO condition resulting in a petite female who requires estrogen supplements to go through puberty (Fausto-Sterling, 2000; Imperato-McGinley, 1992). Kleinfelter's syndrome is another chromosomal error, resulting in a 47 XXY male who will be eunuchoid if he is not treated with androgens at the time approximating puberty (Fausto-Sterling, 2000; Imperato-McGinley, 1992.

Discussion of these conditions naturally leads to the questioning of biological sex. This becomes a good opportunity to discuss intersex individuals. One example of an intersex condition would be the XY female who is produced by Androgen Insensitivity Syndrome (Fausto-Sterling, 2000; Imperato-McGinley, 1992). Another example is Congenital Adrenal Hyperplasia, which produces an XX individual whose genitals can vary from a girl with a big phallus to 'It's a boy' in appearance (Fausto-Sterling, 2000; Imperato-McGinley, 1992; Bleier, 1986).

Discussing the varieties in biological sex serves multiple purposes. The examples help answer the questions of 'why do we need to know this?' for meiosis, while also foreshadowing the discussion of endocrinology. In addition, they help educate these young adults about the true spectrum existing in human biological sex.

Inclusion and relevance

Inclusion is not necessarily contained within sociocultural 'norms'. While students are sexual beings, their sexuality may not fit within the constraints of sociocultural 'norms'(Haynes, 1999; Pohan & Bailey, 1997). Regardless of which statistics one believes, the odds are that any science teacher will have at least one GBLT student at some time in his or her career. Awareness of this fact is particularly important as those sociocultural norms are often rigidly enforced in schools, by student behaviour, as well as official curriculum (Epstein & Johnson, 1994; Nayak & Kehily, 1997; Pohan & Bailey, 1997).

The 'norms' of heterosexuality and masculinity are established in schools in part by peer interactions. I think we are all aware that 'fag' and 'a girl' are common insults among school-age boys (Nayak & Kehily, 1997). If classroom discussions of sexuality are constrained to reproduction, then the teacher is contributing to the social construction of sexual 'norms' and gender roles. Sexuality is presented as being limited to the production of babies (Redman, 1994; Lloyd, 1993). This reinforces the heterosexual 'norm'.

In addition, by focusing on reproduction, the teacher would also be implying that sexuality is not an issue for persons who are elderly. As the elderly population has one of the fastest rising AIDS rates, this certainly is an incorrect perception (Key & DeNoon, 1994, 1998).

An unusual example of inclusion working in the classroom was a result of a class discussion of female genital mutilation, sometimes called female circumcision. I include this topic as part of my class, because the nursing and physical therapy student may be

called to deal with the immediate or long term health risks which this practice can create (Barstow, 1999; Brady, 1998; Ortiz, 1998). During one of my classes, a student announced that this had been done to her at the age of 5 years. She then proceeded to ask several questions both during and after the class meeting (Personal experience, date withheld). This topic was obviously relevant to her life, and her reaction to the topic made it relevant for the rest of the class.

The false gender dichotomy

Male and female tend to be presented in western culture as a distinct, unchanging, and natural dichotomy. This denies the existence of intersex individuals, which are acknowledged in writings from ancient Greece and Rome, and also Jewish religious texts (Fausto-Sterling, 2000). This false dichotomy of male and female has produced misconceptions in medicine: for example that pre-menopausal women can not have heart attacks, and that men can not have breast cancer (300 men die of breast cancer every year in the United States, Guyton, 1996).

One particular example of how this false dichotomy extends into the sciences is the classic presentation of the estrogenic hormones as 'female', and the androgenic hormones as 'male'. The scientific world has been aware since the 1930's that the adrenal glands and the gonads of all people make both androgens and estrogens, regardless of the apparent gender of the body (Fausto-Sterling, 2000; Van den Wijngaard, 1997). Medical reasons for knowing about androgens in the female body include the loss of libido after oopherectomy, and masculinization caused by ovarian or

adrenal tumors (Angier, 1994; Zussman, Zussman, Sunley & Bjornson, 1982). Medical reasons for knowing about estrogens in the male body include normal spermiogenesis, and the risk of breast cancer in the primordial breast tissue of the male (Guyton, 1996; Austin & Short, 1982)

Creating a new 'norm' in the classroom

As a teacher, I am an authority figure, whether I choose to be a facilitator or a lecturer. As such I have chosen to be conscious of the social climate in my classroom, and of the 'norms' which I create, and those which I enforce.

One norm which I support is the idea that my students are adults, with the responsibilities that this entails. If a student expresses a derogatory statement towards a peer, or uses a gendered or sexual term as an insult, I advise the student that he or she is acting unprofessionally. Professional behaviour is important to these students, as they are either anticipating or already experiencing their first clinical courses.

Another norm I create is that the discussion of sexuality is not 'naughty', but instead is relevant to their course of study. I am open about assuming that some of my students are sexually active, and that some of their future clients will also be sexually active. I provide examples of instances when a client or patient's sexual activity would be of relevance. One example would be lymphadenopathy on an athlete's groin as a symptom which must be followed (possible diagnoses, a sexually transmitted disease or a lymphoma). Another example would be a post-heart attack patient, who wants to know when it would be safe to resume sexual activity (Gondek, 1999).

In discussion of situations where the students might be making a sex-related decision, I refer to 'which ever gender is appropriate for you' rather than 'boyfriend' or 'girlfriend'. I have also switched to the term 'partner' when talking to an individual student. The idea is that I am openly not assuming that the students are heterosexual. At the same time, I am modeling language that they might choose to use as practitioners.

I also offer students the opportunity to peer-teach contraceptive and safer-sex methods, using school materials. This allows for 'ownership' of the topics, and also provides an opportunity for practical experience in clinical teaching.

Conclusions

I see sexuality as an important topic for science educators, and for those teaching science education courses. Our students, and their future students or clients are sexual beings. The social, psychological and biological aspects of gender and sexuality are important to our students professionally, as well as personally. Helping our students to think about the diversities of sexuality and gender in a 'safe' environment will provide them with needed tools for their professional practice. By our actions as teachers, we can provide examples of respectful vocabulary and attitudes, as alternates to those presented by the dominant culture.

Sex and sexuality are not well represented in the introductory science textbooks. Presenting male and female as a dichotomy misrepresents the actual functions of human biology. Such a presentation has resulted in medical misconceptions by both practitioners and patients. This false dichotomy also denies the existence of intersex individuals.

Most textbooks limit the discussion of sexuality to a description of human reproduction. This ignores the varied roles which sexuality serves for the human species. Some of the related topics might be beyond the confines of a science course. However, I believe that a brief gesture in the general direction is appropriate, if only to demonstrate to the students that the teacher is informed that they exist.

While my student base is more health professional than education major, I believe that they share the common concerns of the helping professions. Science teachers should be concerned with the cultural and sexual diversity of their students, and with the cultural climate within their classrooms. Science teachers should be concerned with the relevance of what they teach for those students. Teachers of biology should have an understanding of the scientific complexity of biological sex and sexuality. They should also understand the importance of a safe environment for the students who are learning about these topics.

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DRAWING ON THEIR UNDERSTANDING: USING ILLUSTRATIONS TO INVOKE DEEPER THINKING ABOUT PLANTS

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Student created drawings are one of several meaningful tools that can be used to assess science concept knowledge, observational skills and the ability to reason. While drawing is often used with young children before they have gained skills in other forms of communication such as reading and writing, it is not used as often with older students as writing becomes emphasized in the curriculum. Elementary teachers of younger students are often expected to glean information and understanding from students' drawings, yet drawing may not be a tool with which they have had recent experience. As with younger students, drawing may help pre-service teachers think about their own understandings. Further, it may help pre-service teachers understand the strengths and limitations of using drawing to understand student beliefs.

Pictures drawn by a child can reveal how he or she perceives an object, and the degree to which a child observes details and represents them. They can serve as a "window" to a child's concept knowledge. For example, a child's drawing of a plant is likely to not only reflect what he or she knows about the structure of a plant, but may provide information regarding their theories about plants, such as what they need to grow, or what they look like under the ground. Using student drawings as a tool for understanding beliefs is particularly useful when the student has not yet learned to read or write. When pre-service teachers draw to express their beliefs, the process can generate the same kind of deeper thinking as it does in younger students. When included as part of their curriculum, pre-service teachers can also examine the benefits, as well as the limitations, of using drawing as a tool for understanding student beliefs. Thinking about the details of an object during the drawing process is likely to motivate the learner to notice more

specific information in subsequent observations. They may notice discrepancies in their own thinking about a concept and in the way they have either observed an object or phenomenon, or represented it. Drawings have personal relevance, and are helpful to the learner's process of figuring out how the world works.

According to Katz (1993), children in the Reggio Emilia schools in Italy use graphic languages, such as painting, drawing, constructing, collages and puppets to represents ideas and to document experiences. These representations allow children to further explore their understanding of concepts, as the process of drawing provokes questions and invites clarification. As a result, children reconstruct earlier concepts, and are able to revisit their representations in order to more completely understand an idea. Children can use drawings to problem-solve, or to re-think an idea. In this way, drawing is both a learning experience and an embedded assessment. Embedded assessments build upon teaching practice, rather than interrupting the process.

Drawings have been described as being more fair and less-biased assessments of children in that children choose what and how to draw, and their drawings are personal and related to their own experiences. Children's drawings express their diverse interests and are reflective of individual learning styles. When used for assessment purposes, they serve to inform the instructional process and allow for teachers to be responsive to individual interests, background knowledge and emerging skills. Assessments of this kind actually foster teacher development as they tend to hone the teacher's skills in observation, interpretation, and scaffolding techniques.

Understandings of Plants

During the elementary grades, children build understanding of biological concepts through direct, concrete experiences with living things, their life cycles, and their habitats (National Research Council, 1996). Research has shown that children and adults often develop understanding about their physical and natural world which are quite different to those presented by the scientific community (Osborne & Freyberg, 1985, Angus, 1981). For example, children often ascribe human characteristics, or anthropomorphic explanations, to organisms as they interpret the organism's attributes and functions with respect to their own experiences. As students gain a variety of experiences related to the characteristics of plants and animals, it is expected that their views will also change. However, even when students have a variety of concrete experiences, there are often some aspects of scientific phenomena that are so different than human experiences that the development of scientifically accepted ideas can be rare, and misconceptions can prevail.

Related to studies conducted by other researchers (Bannister, 1998; Arnheim, 1969; Dove, Everett, & Preece,1999; Rennie, & Jarvis, 1995), we have found that using students' annotated drawings of plants has helped us to understand their ideas about plants and what they need to grow. Annotated drawings have also provided a useful tool for discovering student misconceptions and planning for instruction that will help each student's conceptual development.

According to the National Science Education Standards (NRC, 1996), students in grades K-4 should understand that: plants have basic needs that include air, water, nutrients, and light; each plant has different structures that serve different functions in growth, survival, and reproduction; and that plants have life cycles that include being born, developing into adults,

reproducing, and eventually dying. Researchers such as Roth (1985) have developed lists of common misconceptions about plants and plant growth. They include:

- Plants can live and grow only in the light;
- Food for plants is either fertilizer/plant food, things plants need like raw materials such as water, sun, fertilizer, shelter, or things plants take in or "eat" (raw materials such as water, fertilizer, sun);
- Plants get food from soil and water;
- Plants get food from many sources (as humans do);
- Anything that is taken into the body or that helps an organism live could be considered food.

In light of students' direct experiences with plants, many of these misconceptions seem to be reasonable assumptions in understanding the function of plant parts and what plants need to grow. It is through experiences teachers create to help students develop deeper understandings that students will be enabled to move beyond the misconceptions listed above.

Setting the Stage for Reflective Drawing

The sample included 76 children who participated in a summer science day camp program in which a broad science topic was the focus. The children, ranging in age from 2 to 12, were asked to create drawings before and after each camp session. At the beginning of the camp session "On the Grow: Michigan's Flowers, Plants and Trees" the children were asked to think about what they knew about plants, the parts of plants and how they grow. Then they were asked to draw a plant, and to include and label as many details as possible. Young children dictated their thoughts to their teachers, who transcribed them onto the drawings. Pencils, fine-point markers, and colored pencils were provided for their drawings. At the conclusion of the camp session, children were given the same drawing task so that any differences in the levels of

understanding could be analyzed. In addition, teachers were asked to provide information regarding the types of experiences children engaged in during the camp session, and the particular concepts about plants that were the focus of those experiences.

Similarly, seventy-seven pre-service teachers, who were enrolled in an elementary science methods course, were asked to create drawings of a plant. The drawing activity took place during the second week of course activities and the pre-service teachers had not studied plants as part of the curriculum for the course. The directions were:

> Think about what you know about plants; what they look like, and how they grow. Draw a plant. Draw (or label) as many things about the plant as you remember. In your drawing include what the plant needs to grow. Write down words, or label your drawing, to help us understand what you drew.

In addition to their plant drawings, each student was asked to answer a question related to plant growth. The question was taken from the *Minds of Our Own* (Annenberg CPB, 1997) video series in which college graduates are questioned about plant growth. The graduates in the video, and pre-service teachers in the sample, were shown a seed and asked to imagine that it was planted and grew into a large tree. Then they were shown a log and told to imagine that the log came from the tree. The question posed was, "Where did all the stuff come from?" With the pre-service teachers, the question was clarified so that they understood "stuff" to mean the "ingredients that made the log" when it was known that the plant started from a small seed.

Learning from Student's Drawings

We analyzed drawings of plants created by the young students who had been involved in the week long summer science camp that focused on the topic of plants and plant growth. Although the children had created drawings before and after the camp experience, only the pre-experience drawings are described here. We used the same process to analyze pre-service

teachers' drawings of plants. For the pre-service teachers, the information provided about what plants need to grow was compared to written responses to the question posed about plant needs.

Using a formal coding process, each drawing was analyzed for the information it provided on: (a) what plants require to grow and; (b) structure of a plant that students were able identify. Analysis of plant requirements included whether these components, or information (labels or transcriptions) about these components were present in the drawings: sunlight/energy, rain/water, soil/nutrients, air, carbon dioxide, indications of the process of photosynthesis, and "other" (e.g., insects for pollination). Analysis of plant structure included the following: roots, stem, leaves, flower, "other" (e.g., petals, stamen). An analysis and count of each of these components within the drawing was conducted separately by two researchers. The results provided very interesting information about conceptual development of ideas about plant anatomy over time.

First, it was clear that at about seven years of age student drawings contained more information and were easier to analyze. Including a transcription of children's descriptions about their drawings is important for understanding young children's drawings. Students ages 3 through 6 most frequently included the plant parts of a stem and leaves, but rarely included roots in their drawings. Across the range of ages (3-12), children drew these plant parts in order of decreasing frequency: stem, leaves, flower, roots. Often, the plant drawing started at the bottom of the stem without the plant emerging from soil or any other matter. Pre-service teachers were likely to represent roots, stems, and leaves in equal amounts in their drawings, while flowers were represented in less than 30% of the drawings (see Figure 1).

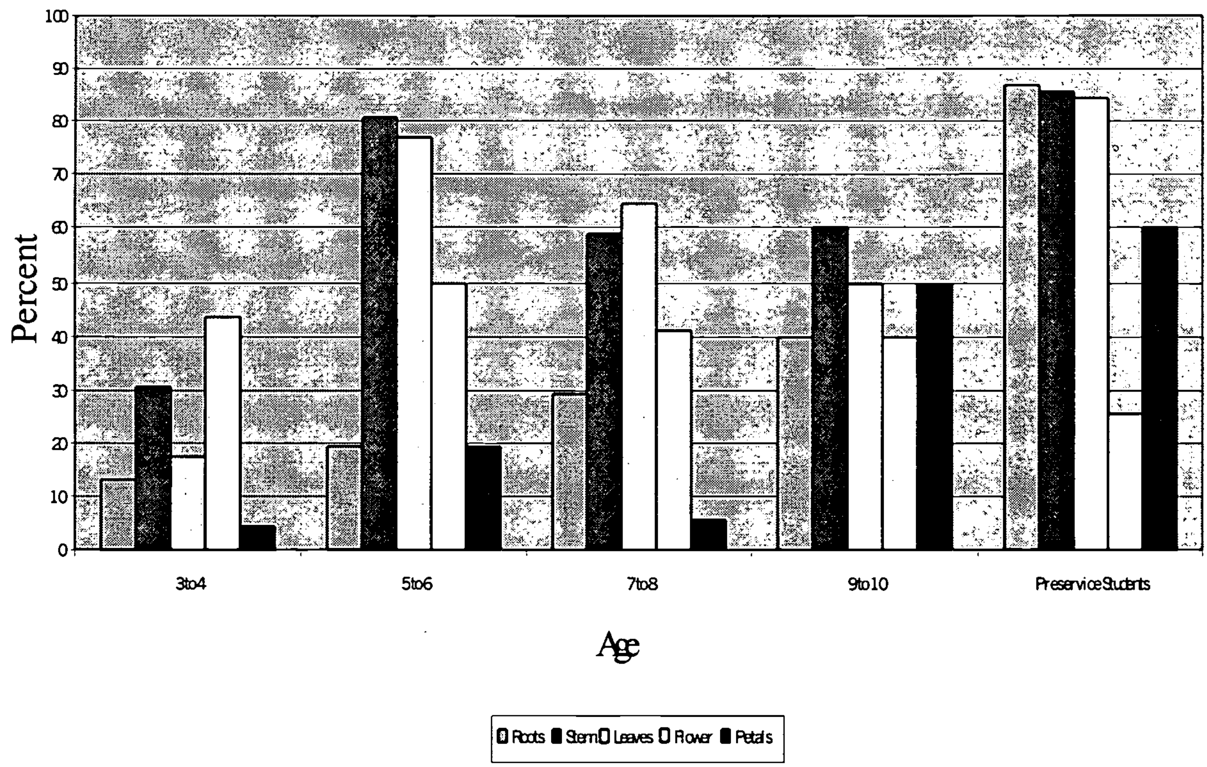

Figure 1. Student Representations of Plant Anatomy

When analyzing the drawings with respect to what students believe plants need to grow, we found some interesting trends. Young children often included sunlight and rain/water as needs, but included soil/nutrients much less frequently. Not one student under the age of seven included air (or carbon dioxide or oxygen) in his/her drawing before or after the camp program. Children and pre-service teachers drew these plant needs in order of decreasing frequency: sunlight, rain, soil, and air (see Figure 2). In the pre-service drawings, it was interesting to note that approximately 30% either labeled, indicated, or wrote "photosynthesis", but less than 10% included the presence of air or other gases in their drawings.

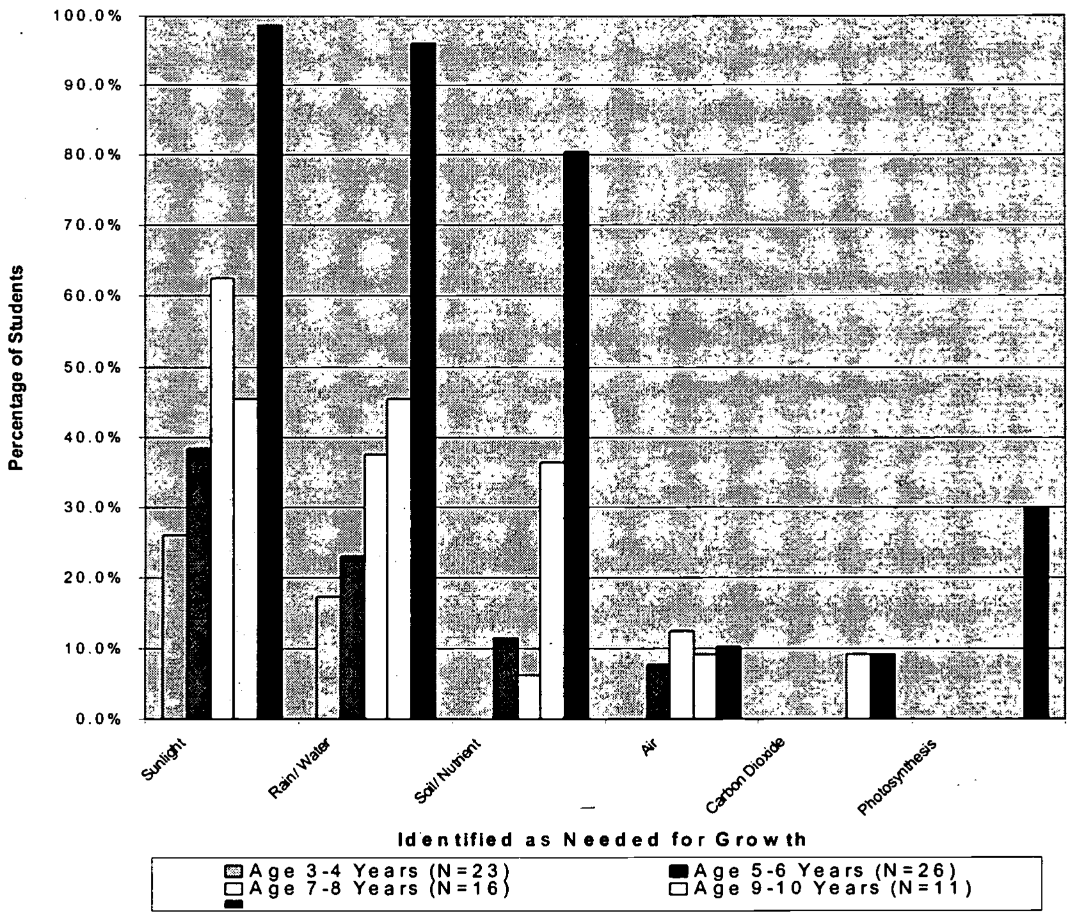

Figure 2. Comparison of Representations of Plant Needs

This discrepancy led the researchers to compare pre-service teachers' drawings to their written responses to the question about "where did all the stuff come from" as posed in the *Minds of Our Own* video. Each student's response was coded using the categories used for coding the drawings. From this comparison it appeared that the drawings included more information than did students' written responses about plant growth (see Figure 3). There are many possible reasons for why this was the case. For example, the question posed in the video was not phrased exactly the same as the directions for the drawing. In some cases it was clear that a student interpreted the question to mean something related to plant growth, but not the

"ingredients" needed for growth (e.g., students provided an explanation of how the genetic code for a plant determines growth). The data represented in Figure 3 indicates that students represented specific materials or processes as being necessary for plant growth better through drawings than in their written responses. However, when reading the written responses, indications of what students' believed and possible misconceptions were much more evident than when analyzing the drawings.

Conclusion

The drawings, even before undergoing a formal coding process, provided a great deal of information about children's emerging understandings. From the drawings it became clear that most students had some knowledge of many of the general plant parts and what plants need to grow. The drawings showed that they often had specific experiences and information that they brought to the learning situation. For example, children who had observed the growth of a bean plant over time drew sequenced stages of growth of the plant in their drawings. Similarly, students would state information such as "the plant needs bees to grow" when they explained why they included a bee in the drawing.

Another frequent observation was that young children's drawings often showed more anthropomorphic characteristics than did those of older children. For example, young children might draw "families of flowers" or plants that had human-like appendages or characteristics. Similarly, young children were more likely to state that plants needed "love" to grow than were older children. Although anthropomorphic characteristics were not evident in the pre-service teachers' drawings, they were often present in the explanations and descriptions provided in their written responses.

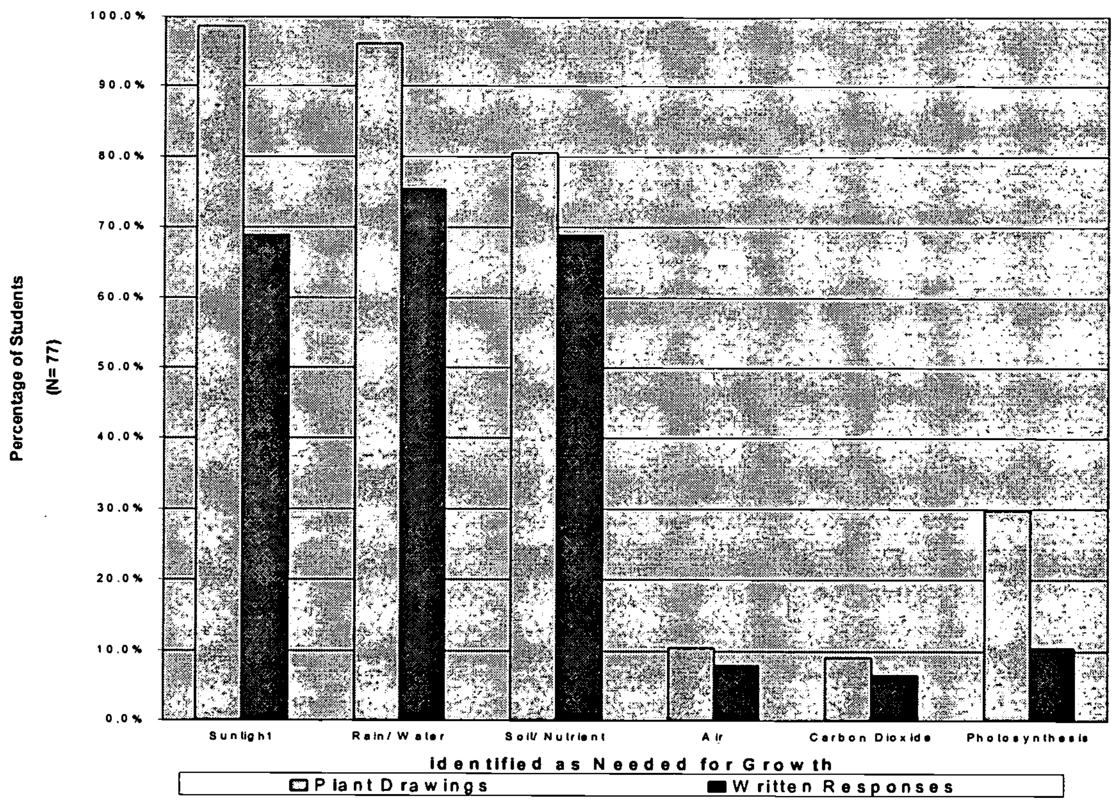

Figure 3. Comparison of Information Provided by Pre-Service Teachers' Plant Drawings and Written Responses

The infrequency of inclusion of some of these components may serve to inform the teaching process as much as when specific items are included in the drawing. For example, it was clear that teachers of young children might begin to focus students' attention on specific areas of study for which the children may be ready. For instance, teachers could begin focusing students on parts of the plant that are not visible, such as the roots, or on ideas about what they might draw at the bottom of their stem (soil and roots). In one case, a four-year-old child who was asked to draw a plant before the camp experience, drew "an engine plant." Given that the child lives in an area surrounded by automobile engine plants, and that this child was probably unaware of the curriculum of the camp, it is easy to understand why he drew this. This case

helps to clarify the importance of using some form of pre-assessment to help determine what students bring to the learning experience.

Our experience with using students' drawings as a "window" to understanding beliefs about plants has provided us with some important insights. As a pre-assessment tool, drawings not only provide the teacher with information about student beliefs before instruction begins, but also provide a mechanism for helping students grapple with their own ideas and questions. This strategy may help to engage students in wanting to know more about the particular science topic to be taught.

As a tool for developing curriculum and sequencing of instruction, drawings can help provide insight into what activities will best serve students' learning needs. For example, students can be asked their ideas about how they believe plants differ from people, particularly when a great number of anthropomorphic characteristics are evident in their drawings. Similarly, even older children and pre-service teachers did not include air (or carbon dioxide or oxygen) in their drawings. If a teacher is readying students to learn about the process of photosynthesis, it would be important to bring students' attention to other substances, not directly provided by humans (e.g., humans may water plants, put plants in the sun/soil), that may impact plant growth.

Finally, our results have provided us with information that helps to show the development of ideas over time. It is clear that many pre-service teachers do not understand plant growth. While they identify sunlight, water, and soil/nutrients as plant needs, most do not go beyond that level. How then, will these teachers be able to support students' building of their understandings of more advanced concepts? The teacher has a direct and important impact on the development of scientific concepts and must understand scientific phenomena at least one level beyond where

their students need to go. It was not clear from the sample we studied that these pre-service teachers would be able to sufficiently direct individual student learning. We believe that drawings are often an under-utilized tool in science classrooms. Drawings can provide valuable information to the teaching and learning process and, more importantly, they provide an open-ended means for creative expression that is difficult to achieve with other assessment strategies.

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BLOCK SCHEDULING SCIENCE: DOES IT HELP OR HINDER?

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Block Scheduling in Secondary School Reform

Criticism of secondary school education in the United States, as well as the continuing desire to improve instruction and learning, have fueled efforts by administrators and school faculty to investigate restructuring possibilities. Restructuring the school organization impacts the entire operation and has the potential to amplify the effects of other reform approaches (Cawelti, 1995a). Increasing the length of class periods has become one of the most frequently implemented recommendations from the secondary school restructuring movement.

Block scheduling is one of the critical elements of the current school restructuring movement Cawelti (1995a, 1994). In block schedules, the annual number of days of instruction remains the same, but there are fewer class periods per day and each class period is longer in duration than the traditional 45-55 minutes (Hamdy, 1996). In the most common form of modular scheduling, the 4x4 block schedule or accelerated block, students take only four courses a semester. These class periods are 85-110 minutes in duration (Canady & Rettig, 1995). Other forms of block schedule include the A/B Block, in which students continue to take 8 courses but they alternate days, the courses continue all year, and the class periods are 85-110 minutes. In 1992 reports suggested 4% of secondary schools were using a block schedule (TEA, 1999). By 1997, the percentage had risen to 50% of high schools in the United

States on some form of block schedule (National Science Teachers' Association, 1997). This presentation focused on the accelerated or 4x4 block schedule.

Strengths of Block Scheduling in Science

The block schedule is frequently assumed to be particularly beneficial for science teachers (Day, 1995). In the traditional schedule, science teachers express frustration about the lack of time in a fifty minute period to engage the students in multiple instructional strategies such as demonstration, lab, discussion, and independent work or reflection within one class period. Additionally, science teachers often need more time for set-up, clean-up, and instruction than do teachers of other subjects. Surveys have indicated many science teachers and science students prefer the block schedule (Ross, 1998). The longer class sessions compel teachers to consider the essential content and to find effective strategies to engage students for the extended time (Cawelti, 1994; Ross, 1998). Teachers have fewer students per semester and the learning climate may improve in the block schedule (Ross, 1998). In addition, the block schedule provides more planning time and greater opportunity for interactions with colleagues.

Challenges in Block Scheduling in Science

Longer class periods mean fewer class sessions and, usually, fewer minutes of instruction overall. It is estimated that there are 30 hours less instructional time on most block schedules.

With class periods of 85-100 minutes, it is assumed that students can complete a year's worth of study in one semester on the accelerated block schedule. This can become a difficult, if not an impossible task. For example, if a state or school district curriculum contains 10 units of study in a traditional year-long course, those 10 units would need to be taught within one semester. On an accelerated block schedule (one semester or 18 weeks) it would be necessary to cover, on average, each of those 10 units in just 9 (1.8 weeks) instructional days. To illustrate the effect of the accelerated block schedule on time allotment to science content, a typical high school biology curriculum can be examined. The Texas Essential Knowledge and Skills (TEKS) in Biology (Texas Education Agency, 1997) is an example of a state mandated curriculum that has biology content divided into 10 units. The cell biology unit covers nucleic acids, mutations, genetic variation, protein synthesis, genetic disease, and cell reproduction. On the accelerated block schedule, each of these six topics would be allotted approximately 1.5 (9 class days divided by 6) days.

In Texas, for the 1997-1998 school year, 13% of high schools were reported to be on the accelerated block and 32% were reported to be on either the AB block (full year but class meets every other day) or a modified block (Region Education Service Center XIII, 1998). This means that approximately 45% of Texas schools have biology teachers who must plan a year-long curriculum in 90 days.

Reported Effects of Block Scheduling on Science Achievement

Studies on achievement and scheduling are conflicting as to whether the achievement of students in science is affected by scheduling. A few studies indicate that block scheduling negatively impacts science achievement. In a large-scale study, Bateson (1990) examined the effects of the block schedule versus the year-long timetable on science achievement of 30,116 Grade 10 students in British Columbia. The results from this study indicated students in the year-long course significantly outperformed students in the semester courses in content knowledge. Bateson replicated his study in 1995 using a large-scale study of 130,000 students and found that, in both mathematics and sciences, students in the year-long course significantly outperformed students in student knowledge in both the semester block and "Copernican quarter" block courses (Marshall, Taylor, Bateson, and Brigden, 1996). A large-scale study by Wild (1998), that used the *British Columbia Grade 12 Provincial Examinations* as an indicator of student achievement supported Bateson's conclusions. In all subjects, there was a trend towards higher marks and higher percentages of A's from students in all-year schools versus students from block-scheduled schools (Wild, 1998). In the United States, students on year-long traditional schedules achieve higher scores on the Advanced Placement Biology Examinations than students on block schedules (College Board, 1998).

However, several studies (Einender & Bishop, 1997, Louden, 1997, Texas Education Agency, 1999) conducted in the United States indicate no effect of scheduling on science achievement.

For example, North Carolina public students showed no significant difference in achievement scores between block-scheduled schools and non-block scheduled schools except in physical science (Louden, 1997). In Texas, a study of all Texas public high schools revealed no correlation between student achievement and type of schedule (Texas Education Agency, 1999).

Socio-Political Influences Related to Block Scheduling

In 1999, in Texas, 46% of secondary schools were using some form of block scheduling. Half of those schools using the accelerated block schedule were located in four geographic regions in the state. The populations in these regions tend to be of lower socio-economic status and include higher numbers of ethnic minorities and English Language Learners (ELL) than in other regions. These patterns suggest the need for more research. There is not enough evidence to determine the rationale for the change in scheduling in disproportionate numbers or the impact of block scheduling on achievement and sense of community among ethnic minority and ELL students.

There is, however, data to suggest the results of some achievement studies involving block scheduling as a variable should consider the confounding effects of language ability. In Texas, the geographic regions with the lowest percentages of passing scores on the End-of-Course Biology test had the highest percentage of schools using the block schedule. However, these regions also had the highest percent of English Language Learners. Student attendance,

socio-economic status, rural vs. urban district, and percent ethnic minority students are a few of the school context variables that associate more strongly with overall student test performance than does schedule type (TEA, 1999).

Block Scheduling and the National Science Education Standards

The *National Science Education Standards* (NSES), formulated to improve all areas of science education in order to increase scientific literacy in students, appear to support a schedule that allows students the opportunity to study science every day of the school year. They state, "science must be allocated sufficient time in the school program every day, every week, and every year. Time is a major resource in a science program." (NRC, 1996, NSES Program Standard D, p. 219). However, it may be easier to implement NSES recommendations under block scheduling conditions. The standards also state, "schools must restructure schedules so that teachers can use blocks of time, interdisciplinary strategies, and field experiences...to engage in serious scientific investigations" (NRC, 1996, p. 44). Science curricula on the year-long schedule are often dilute, diffuse, and fragmented, with too much emphasis on passive learning through lecture and recitation (Cawelti, 1994; American Association for the Advancement of Science, 1990). Block scheduling provides more time for integrated lessons and for the use of a variety of instructional strategies within one class period (Canady & Rettig, 1995; Cawelti, 1993, 1994). Standards for excellence in science instruction suggest using a variety of instructional strategies to teach scientific concepts and processes. The

standards recommend more student involvement in active "hands-on" science, which tends to be time-intensive. The longer class periods permit, even compel, teachers to develop more active learning strategies (Cawelti, 1995), which align more closely with state and national standards for science instruction. The standards also call for the teacher to carefully plan short and long term curricula and to collaborate with colleagues and the scientific community. The increased planning time of the block schedule makes this more feasible. There is evidence, however, that the level to which science instruction changes between schedule types is highly dependent on the belief systems of individual teachers (Ross, 1998). More research needs to be conducted to learn how to influence teachers to modify their instructional practices under the block schedule and to understand the socio-political impacts of schedule change.

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"JUST IN TIME": AN ALTERNATIVE PATHWAY TO TEACHING (APT)

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Background

Pacific University and the Beaverton School District have formed a partnership to establish an alternative teacher certification program known as APT, Alternative Preparation for Teaching, which is offered by Pacific's School of Education under the authority of the Oregon Teacher Standards and Practices Commission. The APT plan has been designed by a team made up of an equal number of Pacific University professors and Beaverton teachers and administrators. The team was co-chaired by Beaverton Superintendent Yvonne Katz and Pacific's Education Dean Willard Kniep.

The purpose of APT is to identify, recruit, and prepare highly qualified individuals to serve as middle and high school teachers of mathematics and science and to provide an alternative and highly attractive avenue for persons with a baccalaureate degree to enter the teaching profession. APT is a fast-track program designed for mature second-career professionals. "Just In Time" refers to the manner in which it was designed. The questions – "What must they know for the first day of school?" "What can we refine later as the year continues?" – guided the design process.

We believe that the development of APT, and the institutional partnership it embodies, is especially timely as both the District and the University face new challenges in connection with the demands of the Oregon 21st Century Schools Act. While the District has an unprecedented

need for teachers who are explicitly prepared to help students meet the increasingly higher mathematics and science standards that are part of the Certificates of Initial and Advanced Mastery, the University must continuously seek ways to more effectively prepare teachers to meet the needs of districts like Beaverton and others throughout the State of Oregon.

These challenges are being made more acute as an aging teacher workforce begins to retire in ever increasing numbers creating a potential shortage of qualified teachers in the years ahead. This problem is compounded even more in areas of acute need such as mathematics, science, special education, and foreign languages as universities are finding it increasingly difficult to attract qualified candidates in these critical areas to teacher education programs.

The APT teacher education program combines professional study with supervised teaching in a year-long paid internship. With the instruction and supervision provided by professionals from both institutions working together, APT interns become actively involved in their own learning. They not only develop fundamental understandings, but also become problem solvers, critical thinkers and creative learners.

Program Overview

APT was launched in May of 2000 with a cohort of 22 students.. Initially the program targeted students seeking middle school and high school authorizations with endorsements in science and mathematics. In subsequent years, the program may be expanded to include additional areas of acute need such as foreign language, TESOL and bilingual educator endorsements, and special education authorizations.

Students

The recruitment strategies for APT targeted non-traditional students, particularly working adults with undergraduate preparation in mathematics and science or related fields who were considering a change of career to teaching. Our preliminary research indicated that there were a number of such individuals working in the "high tech" industries of Washington County. We also identified the armed forces as a potential source of such non-traditional students. In actuality, the applicants came from a great variety of sources, including industry, business, research laboratories, and a variety of positions within educational institutions.

A characteristic of alternative programs nationally – especially those which offer a paid internship – is that they are able to attract more diversity than traditional teacher education programs. That was our experience in the first year of APT as well. Appendix A provides a profile of the first-year APT interns.

Admissions Criteria

The admissions process was carried out by an admissions committee made up of representatives from the District and University. In admitting students to the program, the following criteria were considered:

- Baccalaureate degree in mathematics or science or in a related field.

- Grade point average (GPA) in undergraduate and graduate study. While the desired undergraduate grade point average will be 2.75, mature students with a lower GPA and successful work history will also be considered for admissions.
- Employment history that supports the development of a knowledge base in mathematics or science.
- Evidence of the ability to work on a team to accomplish mutually agreed upon goals.
- Evidence of the ability to support others, to coach others, to solve problems, and to be creative.
- Evidence of a desire and ability to work with children in teaching/learning settings.
- Passing score on the appropriate PRAXIS examination.

Program Design

The design of this alternative teacher education program is an adaptation of Pacific University's teacher education program which was approved by the Oregon Teacher Standards and Practices Commission in July, 1998. The APT program itself was approved in July, 2000. As part of our program approval, Pacific is certified to offer the authorizations for Middle School and High School levels and for endorsements in Mathematics, Biology, Chemistry, Integrated Science, and Physics.

In the design of APT we have made two major adaptations to our MAT/5th Year program. First, in order to accommodate the schedule and nature of this alternative program, we have reorganized the course work into four major blocks to be offered during the summer and a series of seminar based courses which precede and follow the summer blocked courses. Second, in this

program the course work and other experiences are centered around an intensively supported, paid internship in the Beaverton School District.

APT is a 47 semester credit fifteen month program. Students who successfully complete the alternative teacher education program will be eligible to apply for an Oregon Initial Teaching License and will have fulfilled the requirements for the Master of Arts in Teaching degree. A description of the program components follows.

- Orientation to Learning Communities (May)

This seminar-based experience lays the foundation for students' successful participation in the program as it introduces them to the culture of standards-based schools. Saturday seminars and evening classes are designed to build a community of learners among the interns. At the same time the seminars provide them with the concepts and skills they need to see schools and classrooms as communities of learners. Interns schedule themselves into selected classrooms for up to 40 hours of guided observation and participation throughout the month. Students earn a total of three semester credits for the May experience.

- The Pre-internship Summer (June through August)

The pre-internship summer is designed around two overall strands: (a) the foundations and general methods of teaching, and (b) the specialized concepts and methods for teaching either mathematics or science. Each of the strands meet for three hours daily for approximately nine weeks. The foundations and general methods strand is organized into two blocks of four semester credits each. The first block focuses on

foundational topics such as the psychology of learning, learning theories, adolescence, standards based education, assessment, and Oregon School reform. The second block is focused on pedagogical issues including communications, unit and lesson design, teaching strategies, assessment, integration of technology, and classroom management.

In the specialized strand, interns work within a cohort of those preparing to be either mathematics or science teachers. As with the general strand, the specialized strand is organized into two blocks of four semester credits each. The first is focused on topics related to mathematics (or science) education reform and an examination of the processes through which learners develop understanding as a basis for planning and assessing mathematics (or science) curricula. The second block focuses on the pedagogical principles in secondary mathematics (or science) education.

The pre-internship summer culminates with the interns using the District's summer school classrooms as a setting for doing guided teaching under the direction of the program's staff. Students earn three semester credits for this practicum.

- The Internship

The internship phase of the program started in September with the beginning of the 2000-2001 school year. Each intern was assigned a classroom as the teacher of record. Interns earn fifteen semester hours of student teaching credit for the internship.

For each intern, the District contributes to a budget pool an amount equal to the Step 1 figure on the Beaverton salary scale. Seventy-five per cent of that amount is paid to the intern. The remainder is withheld to pay for supervision and to cover

administrative costs as incurred by the University and the District. In addition, the District's medical benefits plan is extended to include the interns.

Each intern is provided intensive support and supervision from a variety of sources, including a Teacher Education Associate, a mentor, the APT Director, and other support services. Each intern is assigned a Teacher Education Associate (TEA) who has the primary responsibility for supervision and for coordination of activities in support of the intern. Teacher Education Associates, who are selected and trained in their role, hold a full time position with the project and are responsible for up to six interns. Their salaries are paid from the budget pool created by the funds withheld from interns' salaries. Appendix B describes the role of the TEA.

Interns are also assigned a mentor teacher – a master teacher in the building or department of the intern who is asked to serve as friend, coach and mentor to the intern on an as-needed basis. Mentor teachers are paid a stipend. In addition, the APT Director makes at least three supervisory observations of each intern during the year and provides evaluative feedback. The Director is also responsible for evaluating two Work Samples and performing the interns' Mid-Year and Final Evaluations. Additional support and supervision is also provided by school-based curriculum specialists and by the building principal.

During each semester, the interns participate in a series of Seminars. During the Fall semester, beginning in mid-October, the Seminars re-focus, for greater depth and application, on the key topics (e.g. lesson design, assessment, classroom management) from the foundations and general methods strand of the summer. During the Spring semester the focus of the seminars is on the development and assessment of the two work

samples required by TSPC. Students earn three semester credits for each series of seminars.

- The Post-internship Summer

The post-internship summer is designed to enable the interns to complete the requirements for the Master of Arts in Teaching degree and to provide a culminating experience for the program. During this time the interns will complete the Introduction to Research course (2 semester credits) and participate in a seminar-based version of the Advanced Teaching Strategies course (2 semester credits).

Salary and Benefits

APT interns receive 75% of the beginning teacher salary, Step 1 (for 2000-1 the salary they received was $23,962 BA or $26,016 MA). This yearly salary is distributed in 12 equal checks. The first pay date was August 20 and the last will be July 20. Interns are provided with family medical and dental Blue Cross HMO or Kaiser benefits. Those teachers who are selected by the district for employment will receive a full teacher's salary, Step 2, beginning on August 20, 2001.

Tuition

APT interns pay tuition to Pacific University for 32 semester credits at the current per credit rate. (For the 1999 – 2000 Academic Year the rate was $350 per credit.) Tuition was waived for the 15 semester credits of student teacher earned as part of the internship. Loans, and other forms of financial aid, were available through the University.

The District also advanced to students eight semester hours of tuition reimbursement against the normal three year allotment that is provided by the District to its teachers. The interns made a written commitment that – if offered a teaching position – they would agree to teach in the Beaverton School District for two years following completion of the program. Interns who do not keep this commitment will be asked to repay the tuition reimbursement advance in full.

Acknowledgements

The key personnel in the development of APT have been the members of the inter-institutional Design Team. This group will continue to provide oversight to the planning and implementation of all phases of the program. The Design Team is made up of the following individuals: Yvonne Katz, Superintendent, Beaverton School District. Co-chair of design team; Willard Kniep, Dean, School of Education. Pacific University Co-chair of design team; Linda Borquist, Executive Administrator for Human Resources, Beaverton School District; Jeffrey Frykholm, Assistant Professor of Mathematics Education, Pacific University; Mike Howser, Administrator for K - 12 School Improvement, Beaverton School District; George B. Moss, Teacher on Special Assignment for Science Education, Beaverton School District; Karen Nelson, Assistant Professor of Education, Pacific University. Coordinator of Beaverton Partnerships;

Camille Wainwright, Associate Professor of Science Education, Pacific University; Nancy Watt (ex officio), Assistant Dean, School of Education, Pacific University.

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Appendix A
2000 APT Program
Class Profile

Twenty-two students were accepted into Pacific University's Alternative Pathways to Teaching program in April 2000. The largest percentage (36%) of these students is between the ages of 31 and 40. Students between the ages of 25 and 30 account for 27% of those enrolled, with another 22% over the age of 40.

Nine members of the class are female and 13 are male. The majority of the students are white, non-Hispanics. Thirteen percent of the students are Asian and another 13% are Hispanic.

The majority (45%) of APT students attended out-of-state schools. Thirty-two percent of the class hold advanced degrees including: PhD in Physiology, PhD in Zoology, MS in Marine Environmental Science, MS in Analytical Chemistry, MS in Physics, MS in Genetics, and an MBA.

Prior to admission in the APT program, 73% were employed in education related jobs. Professionals account for 18% and 9% were students.

This group of students brings a wide variety of experiences to the program. One student travels back and forth to Zimbabwe studying traditional music, dance and culture. He decided to become a licensed teacher after tutoring children in that country. Other students' experiences include:

- Staff scientist for the Oregon Regional Primate Center
- Teacher, 6-8 grades in Ukunda, Kenya
- Professional Engineer and licensed land surveyor
- U.S. Peace Corps worker, Zambia
- Math and Physics lecturer, Ngee Ann Polytechnic, Singapore
- Director of Operations, Mentor Graphics
- U.S. Army Major
- Zookeeper, The Oregon Zoo
- Wildlife Biologist
- Lead Science instructor for OMSI
- Independent researcher, Community Baboon Sanctuary, Belize
- Lab instructor, Texas A&M University

Appendix B

Role of the TEA

(Teacher Education Associate)

The TEA is of prime importance during the APT Intern's first few months of teaching, but that role continues throughout the academic year. The Pacific University School of Education *values education as a lifelong progress*, and provides TEAs for assistance to Interns in their ongoing professional growth.

During the first few months of school:

The TEA will:

- Visit classrooms at least weekly for both formal and informal observations
- Provide guidance in the development of classroom management procedures and instructional strategies
- Assist with classroom design, posting student work, preparation for Back to School night, organizing gradebook and seating charts, preparation of progress reports, and other logistics
- Advise Intern on appropriate classroom safety techniques
- Build morale, provide a 'listening ear', act as a 'sounding board'
- Help locate resources needed for lesson planning, including appropriate utilization of technology in instruction
- Review lesson plans during each observation visits (plans to be regularly filed in a notebook for each prep)
- Recommend techniques to foster and facilitate communication with parents and with administrators
- Act as a liaison between the Intern and the District
- Meet regularly with the Pacific University APT Director for clarification of program expectations.
- Teach a model lesson (if requested by Intern)
- Assist with lesson planning (if requested)
- Sub for a period or two so Intern can observe other classrooms (if requested)

The TEA IS:

- an experienced professional with excellent classroom skills
- the Interns' advocate and primary support person in the APT program
- a colleague with whom the Intern can share ideas, problems, and concerns.

The TEA is NOT:

- an automatic substitute teacher
- the evaluator of the Work Sample
- the evaluator of teaching.

<u>Throughout the school year:</u>

I. Teachers who complete Pacific University teacher education programs will model and promote *personal* awareness and intellectual rigor.

TEA's will assist Interns in:

- reflecting critically on their own practices
- evaluating and questioning educational theory and practice
- understanding the value of research in informing practice
- maintaining openness to new ideas
- developing a healthy skepticism
- demonstrating flexibility and creativity
- continuing to develop a personal teaching style.

II. Teachers who complete Pacific University teacher education programs will possess *relational* and instructional skills that emerge from a commitment to effective communication, collaboration, and the celebration of diversity.

TEA's will assist Interns in:

- developing and utilizing a comprehensive repertoire of instructional strategies
- designing curricula that appropriately integrates disciplines
- creating student-centered environments that promote inquiry
- promoting the active construction of student understandings
- accepting and nurturing a broad range of learning styles and intelligences
- designing activities appropriate for students' developmental levels
- recognizing the impact of language and culture on student learning
- continuing to expand their receptive and expressive communication skills.

III. Teachers who complete Pacific University teacher education programs will possess the knowledge, attitudes, and competencies to model and promote active participation in the *community*.

TEA's will assist Interns in:

- providing leadership and service within the profession and education organizations
- demonstrating respect for local and global environments and communities
- developing and supporting democratic learning communities
- recognizing and valuing the interdependence of communities
- thinking systemically about the context surrounding the learner
- considering the school in its socio-political context
- understanding and participating in both conservation and change.

ISSUES IN THE PREPARATION OF TEACHERS TO FACE THE CHALLENGE OF THE BLACK-WHITE ACHIEVEMENT GAP IN SCIENCE: "I LOVE YOUR QUESTIONS, BUT WE HAVE TO GET THROUGH THIS STUFF."

Charles R. Ault, Jr., Lewis & Clark College
Obed Norman, Washington State University Vancouver

The Performance Enhancement of African American Students in Science (PEASS) Project

The National Task Force on Minority High Achievement, formed in 1997 by the College Board, has asked why the performance of certain minority students lags behind that of their White and Asian-American counterparts. After an extensive review of the issue (Jencks & Phillips, 1998) the Task Force recommended systematic and sustained research efforts to determine the reasons for such disparity in achievement. The work of PEASS is one answer to this call. This paper reports on one outcome of PEASS research: a case study analysis of interaction patterns over three months in required seventh grade life science and eighth grade earth science classes taught by the same white, male teacher at an urban middle school with a predominantly African American enrollment.

The National Assessment of Educational Progress has documented relatively lower achievement of African American students as measured on standardized tests (Mullis, Dossey, Campbell, Gentile, O'Sullivan, & Latham, 1994). Ogbu and Simmons (1998; Ogbu, 1991) have accounted for this phenomenon in terms of Cultural-Ecological Theory, the result of three decades of research comparing the achievement patterns of minorities in societies around the world. According to Cultural-Ecological Theory, the process of becoming and the continuing

status of being a minority shape beliefs about schooling. Members of the same racial or ethnic group may perform at high levels in one socio-historical context but at a lower level in another setting. Ogbu's comparative approach replaces concern about race and ethnicity as direct contributors to disparity of performance with attention to social context, relationships of power and identity, and ideas about assimilation into the dominant culture.

With Ogbu's theorizing in mind and following a two-day training workshop in "participant observation" led by Ogbu, and the authors, PEASS researchers turned their attention to interaction patterns in science classrooms with a very high proportion of African American students from low-income, urban neighborhoods. PEASS sent multiple observers to eight different schools to observe classrooms, conduct interviews, and collect performance data. This paper reports only on the case study findings about interaction patterns in one middle school science as observed by a single classroom observer during the first year of a five-year study. PEASS observers—working either from the discipline-based perspective of science educators or the culturally attuned perspective of community members —have also collected data in other elementary, middle, and secondary schools.

Notably, publicly posted test scores ranked the middle school studied extremely low in academic performance within the state even in comparison with other schools of comparable socio-economic status (Office of Assessment and Evaluation, Oregon Department of Education [ODE], 2000; ODE, 2000). According to the profile of the school, 76% of its eighth graders scored below state benchmarks in mathematics and 65% below the benchmarks for reading. Only 8% in mathematics and 15% in reading exceeded state benchmarks (the remainder were classified at "meeting benchmarks").

By comparison, a middle school at the top level of performance and socio-economic status in the district reported 14% of its students failing to meet reading benchmarks, 63% exceeding; 25% not meeting those for mathematics, 30% exceeding. At this school, 30% also exceeded the state benchmark for science knowledge (27% did not meet the science benchmark). At the study school, 75% of the students did not achieve a score meeting the state benchmark for eighth grade in science; 2% did exceed this score. At the "high end school," fewer than 7% of the students received free or reduced-price lunches; 87% were white, 3% Black, 4% Hispanic/Latino, 5% Asian/Pacific Islander, and 1% Native American.

At the "low-end" middle school (one of two middle schools with predominantly African American enrollments observed as part of the first year of the PEASS project), 53% of the students in 1999-2000 were African American, 25% white, 11% Hispanic/Latino, 8% Asian American/Pacific Islander, and 3% Native American (ODE, 2000). Nearly two-thirds of the students came from low-income families; 59% participated in the reduced or free lunch program (ODE, 2000).

PEASS aims

As a partner with the school district, the research team addressed a number of questions. For example, the district in approving the research proposal stated that it expected to learn:

1. The relationship of curriculum material and instructional methods across grades and school type.
2. The role of student sub-culture variables in achievement.

   The participating classroom teachers joined the project in order to make changes in their teaching that might lead over the next 3 years to improved student performance. They have

acknowledged the importance of addressing the problem of the disparity in achievement between African American and white and Asian students as reported through the media and research literature. They deserve unwavering support for they are those most willing to take risks and examine their own teaching with courage.

The middle school science teacher whose lessons provided the grist for this paper has taken an exceptional risk. Although the conclusions embody deep criticisms, readers are advised at the beginning to apply such criticism at a system level and consider the individual teacher in a heroic light. There are no villains in this story. There are episodes of instruction and daily experiences of one valiant teacher doing his best. It is also the narrative of students who have enormous needs. If this study succeeds, the success will come a few years in the future when a companion manuscript describing the same classroom and teacher tells a very different story from this one.

PEASS investigators planned to investigate, in keeping with these district aims, how teacher-centered and student-inquiry practices unfolded in classrooms with predominantly African American enrollments. Several other questions have emerged to guide PEASS researchers over the next three years:

1. What aspects of schooling do students find marginalizing or alienating?
2. What practices have succeeded in re-engaging resistant students to school and learning?
3. What practices have prevented disengagement?
4. How do teacher-centered lecture approaches differ from inquiry approaches in their impact on science learning of different students?

5. How does language operate in the context of science learning by African American students?

At this preliminary stage and through the case study of middle school science teaching representative of a troubled classroom, the PEASS project has achieved tentative answers to questions one and five above. Our answers stem from observing teacher-student interaction spiraling downward in a "debilitating cycle of misconceived rigor." With this interpretation of the problem in mind, the intent is to work with the classroom teacher over the next three years to find answers to questions two through four. We wish to determine through empirical work and theoretical interpretation which classroom interactions are crucial for enhancing African American student performance in science while coming to understand how these interactions might be both cognitively and culturally responsive to individual learners.

Attention to Discourse

The work of Lemke (1990) informed the fifth question and figured significantly in the analysis of the middle school case reported in this paper. Lemke found that difficulties learning science are often due to incongruities between the unfamiliar discourse patterns of science and the familiar ones of students' own discourse styles. In the middle school studied, the teacher's use of "analogy" to help students form new abstract ideas confirmed Lemke's assertion. In addition, Lemke argued that power relations impact learning experiences, generating patterns of interaction that may be productive or unproductive in terms of student performance. If only in terms of dwindling attendance, particularly in the eighth grade, PEASS findings confirmed Lemke's view.

Overview

Classroom observation notes reported in this paper were taken during eight visits spanning three months by a single observer in keeping. These notes kept track of room

arrangement, curriculum content, time, instructional behaviors, student responses, and classroom management. The notes included direct quotations, though not taken from audio-recordings, and kept track of race and gender whenever a student interacted with the instructor or another student.

Following general information about the room, textbook, and instructor, patterns of classroom interaction are summarized and interpreted. These patterns constitute, in briefest terms, a very coercive cycle of rote study that defeats meaningful learning. This judgment, based primarily upon classroom observations, may tempt readers to blame the teacher. That would be a mistake. As Ogbu has argued most persuasively, attempts to understand pedagogy and student performance fail unless they address community forces in detail. Community forces are political as well as cultural; the politics of school reform progressively demand closing the achievement gap while at the same time retrogressively coercing teachers into covering prescribed content in preparation for high stakes examinations designed with forced-choice formats (e.g., multiple-choice). An unproductive, coercive, mind-numbing environment finds favor with no one, especially a caring adult. Significantly, the classroom teacher observed in this study has begun to question seriously his future as an educator, and one-third of the students in his eighth grade section of earth science have ceased to attend class regularly.

<u>A Debilitating Cycle of Misconceived Rigor</u>

The data frame an image of a "debilitating cycle of misconceived rigor." Gowin (1986) eloquently captured this pattern of mis-educative practice: "There abounds a false idea of knowledge. This false view leads to a debilitating rigor. This obsessive rigor leads to a silencing: Questions of fundamental interest are forbidden. Therefore, questions not asked result in a false

idea of knowledge. ***The cycle is safe and therefore popular.*** " The subtitle of this paper, a statement quoted directly from the classroom teacher, expresses the same sentiment. The imperative of covering science content in verbal form silences student questions while devaluing their imagery and expression, thus birthing the false idea of learning as remembering. Belief in this false idea of knowledge offers reward to the complacent who earn praise while disciplining themselves to accomplishing brutal levels of memorization, never questioning or appreciating the purposes or worth of the ideas in science they are expected to learn. The political community presumably directing the course of public schooling in science manipulates the rewards and punishments that foster this pattern. The pattern fails, in the phrasing of Darling-Hammond, each student's "right to learn" (1997). The pattern also debilitates the teacher's right to teach for understanding.

In the midst of this depressing scenario the dedication of several African American female students in seventh grade deserves attention. These students asked questions, completed assignments without complaint, attended class regularly, assisted fellow classmates, and volunteered to answer questions. Frequently, their responses included an element of inference or application going beyond recall or simply finding a statement in the text. Also, in the midst of this portrait, there exists affection between the teacher and his charges.

The task presented to the remainder of this paper is to justify the judgment that a debilitating cycle of mistaken rigor typified science instruction at this middle school. Unless broken, this cycle threatens to maintain the achievement gap. In terms of the questions representing the aims of the PEASS project, the cycle promotes marginalization and fails to

bridge between the personally meaningful discourse patterns of students and the formal ones of science by omission of carefully crafted experiences.

Revisiting John Dewey

The work of John Dewey in effect acknowledged the "debilitating rigor" problem. He characterized this challenge as one of "pscychologizing" the curriculum: "Hence the need for reinstating into experience the subject-matter of the . . . branches of learning. It must be restored to the experience from which it has been abstracted. It needs to be *psychologized*; turned over, translated into the immediate and individual experiencing within which it has its origin and significance" (Dewey, 1990, p. 200). Disciplines, with their constellation of resources for solving problems, have abstracted from experience patterns with saliency within the context of the discipline's purposeful agenda. The words and concepts of science are "dead and barren" (p. 202) unless connected to the child's experience. "The lack of any organic connection with what the child has already seen and felt" (p. 202) and the "conspicuous absence" of "need and aim" (p. 203) for the subject matter become the principle mis-educative evil: "Those things which are most significant . . . and most valuable in the logic of actual inquiry and classification drop out" (p. 204).

Thus do school curricula eviscerate bodies of knowledge. The problem of finding laws of motion universal to both mechanical and electromagnetic phenomena and the challenge of understanding the photoelectric effect of light that once provoked Einstein's deepest theorizing appeared in middle school science as definitions of waves and particles to memorize and a weakly constructed analogy to appreciate (high and low speed arrows fired at a target and radiant energy striking a metallic surface). Lacking "the logic of actual inquiry" and without "organic

connection," seventh graders confronted the expectation that they learn the wave-particle duality of light—in isolation from any "need and aim" to interpret a puzzling experience. Many paid little attention; few, if any, comprehended the subject.

Contextual Factors

Overwhelmingly, for three months students responded to teacher-directed, text-centered activity in the science classes observed. Seventh grade students studied light energy; eighth-graders, plate boundaries and the rock cycle. They focused their attention either on the teacher and the teacher's notes on the board or screen at the front of the room or upon worksheet packets that came with the textbook adoption that they completed either in class or as homework.

Room Arrangement

The room had movable desks arranged in islands of from three to five desks. The school was built as a high school with appropriate science classrooms and had four lab workstations with sinks and hook-ups lining each wall. The teacher kept a desk at the back of the room and a demonstration table at the front, along with an overhead projector. To one side were windows; in the front, a blackboard and screen. There was an unused hood system at the back of the room and a storage and preparation space adjoining the classroom and connecting with the adjacent one. Space was ample for 30 students. In summary, the room was typical for middle school science teaching and posed no evident constraints on how a teacher might organize instruction.

Textbook Adoption

The district recently adopted Prentice Hall's Science (1997), The American Association for the Advancement of Science (AAAS) assigned this series the lowest rating in terms of

"instructional quality" among ten middle school science textbooks reviewed (Project 2061, 1999). AAAS found all ten textbooks "unsatisfactory": "The analysts—middle school teachers, curriculum specialists, and professors of science education—found that the textbooks covered too many topics and didn't develop any of them well. The texts . . . included many classroom activities that either were irrelevant to learning key science ideas or didn't help students relate what they were doing to the underlying ideas" (p. 1). The point to keep in mind is that the teacher observed in the PEASS project had no choice about curriculum. He was responsible for covering the chapters in the adopted text and well understood that district-wide, state authored, multiple-choice science testing of eighth grade students loomed on the horizon. Students in the seventh grade studied light energy during the study period; in the eighth, the rock cycle and plate margins.

Enrollments by Race

In both classes Black students comprised the largest racial/ethnic group, reaching nearly 50% of the enrollment. The roster for seventh grade listed 31 students: 7 Black females; 7 white females, 7 Black males; 3 white males; 1 Asian male (Chinese); 4 Latino/Hispanic females; 2 Latino/Hispanic males. One of the Black males also claimed identity as a Native American; another was a recent Polynesian immigrant. Another Black male student characterized himself as "Black-'rican" (from Puerto Rico). None of the white students was a recent immigrant.

The roster for eighth grade listed 30 students: 8 Black females; 5 White females, 2 Latina/Hispanic females; 1 Asian female (Indian), 1 Native American female; 6 Black males; 5 white males; 1 Latino/Hispanic male; 1 Asian male (Vietnamese). Two of the white students (one male, one female) were recent Russian immigrants. Clearly, bi- and multi-racial categories

would more accurately reflect the diversity of these two classes. This oversimplification, however, did not obscure patterns of interaction pertinent to the principle aims of the study.

Classroom Teacher

The instructor, a young white male, earned his license as an elementary teacher and had taught for only a few years at the middle school level. (Middle schools in the district where PEASS conducted research employ a mix of elementary and secondary licensed science and mathematics teachers. The state instituted a middle level license only two years ago. Elementary licensed teachers are presumed to have a general knowledge of all subjects.) The instructor had worked previously as a craftsman and was knowledgeable about home construction, home utilities, and woodworking—practical applications of technology. He took a special interest in science teaching and exercised leadership of a chapter of MESA (Mathematics, Engineering, Science Achievement extracurricular program targeting African American, Native American, and Hispanic students) at his school.

Classroom observations revealed a teacher that exercised firm, vigilant authority. He was quick to assign warnings and detentions, never hesitant to "coach" the entire class in proper behaviors such as completing work, using time well, etc. He spoke, when seeking attention amidst noise, loudly, but without shouting or anger. Management of misbehavior presented no special challenge and he resorted to praise and rewards (breaks, popcorn party, video) readily.

The classroom teacher created a safe environment where students were not permitted to harass or "dis" (contraction of "disrespect") each other, where consequences for misbehavior were well known and consistently applied, and where rewards were explicit. Students talked freely with him; both he and they made references to skin color casually, for example, when

talking about ultraviolet radiation and sunscreen as part of a lesson on light. Often, students sought his approval; several openly wished to please him. Nevertheless, escalation of disciplinary responses to misbehavior occurred and reached the level of ordering students to the office (twice) and threatening suspensions (eighth grade only). In each of these cases, the students disciplined were African American males. The teacher issued warnings for failure to focus on work, excessive talking out of turn, disrupting others, leaving one's desk without permission, and disrespectful speech. Issue of more than two warnings within a week led to detention. In response to behavior threatening harm (putting tacks on seats), he threatened suspension. One student in the eighth grade (African American male) was on suspension during part of the period of classroom observations.

The data suggest a pattern of calling upon a wide range of students within each class, especially during review sessions, with clear use of "target students" (Tobin, 1990; Tobin & Gallagher, 1987) on a frequent basis. ("Target students" are called upon by teachers to such an extent that they tend to monopolize whole class interactions. According to Tobin and Gallagher, they have higher formal reasoning ability and achievement levels than the other students, are present in most classes, and are often risk-takers.) Notably, the target students in seventh grade physical science were two African American females.

The Eighth Grade Story

In order to tell the story, first go on the adventure. In this section we tell in detail the story of several earth science lessons. Space does not permit a similar telling of the story of seventh grade, physical science. However, the tales do not differ in substance. The style of instruction and the problem of student achievement were common to both classes; the problems

more acute in the eighth grade (and the testing stakes higher). The introductory and concluding sections of this paper draw upon examples from both classes.

A two letter code and number identified students across lessons; "B" for Black, "L" for Latino, "W" for white, "A" for Asian, "PI" for Pacific Islander, NA for Native American, "F" for female, and "M" for male.

First Lesson

Observing eighth grade Earth Science began with a telling situation: while the classroom teacher attended to a hallway altercation, a neighboring teacher stepped into the classroom to call the students to order. She asked authoritatively, "What page are you on?" Students recognized this signal as a familiar one to open their textbooks. The text-driven instructional routine was familiar to both the outside teacher and the students.

When the classroom teacher returned, he admonished the class for its behavior (someone had placed a tack on another student's chair) and distributed a worksheet for students to complete on their own at their desks. They were at the beginning of their study of the rock cycle. As the teacher looked for papers to return that he had graded previously, he reminded the class that answers were "in the book and on the diagram."

Students were conspicuously unable to decipher the diagram. The classroom teacher carefully described the formation of each type of rock (igneous, sedimentary, metamorphic). Unable to find the missing papers, the teacher apologized, and then asked, "Do you want extra time to work on these [rock cycle questions], or do you want me to start the video?" The class voted to see the video on predator-prey relationships, not a topic germane to their study of the rock cycle. The worksheet emphasized vocabulary; there was virtually no science instruction.

(There are 3 special education students in this class: WM10, BF23, and BF. Another adult attends science class to assist them.)

Second Lesson

The next class began with attention focused on notes projected onto the screen at the front of the room. These notes summarized the 3 main types of rocks: "Igneous rocks are rocks that are formed from cooled, molten lava . . . " Students copied these definitions in silence. The teacher admonished them to "mind your own business" and reminded them of the no gum rule.

After 15 minutes, he directed questions to the class in the style of triadic dialogue (Lemke, 1990). "What are the 3 main groups of rocks?" typified the structure of his queries. Students read answers to these questions from their notes. BM29 could not answer correctly; BM11 read haltingly.

"Open to page 97. What is the rock cycle?" asked the teacher to which BM29 responded, "Rocks arranged in a cycle." The teacher, following a common pattern, did not criticize this response. Instead, he elaborated upon this answer in a brief "teacher monologue" (Lemke, 1990) beginning with, "One kind of rock can turn into another."

LM02 then read from the text, "Igneous rocks are classified according to their composition and texture." The teacher stopped him and asked, "How are igneous rocks classified?" LM02 answered and continued reading. Thirty minutes later while working at his desk, LM02 approached the teacher. He was unable to answer the homework question, "How does the texture relate to where the rock forms?" The word "texture" held no meaning for him. With no rocks present to examine, he had no way to construct from experience tangible meaning for this term. He knew the objects of interest only as words.

Students called out answers several times during the lesson and also took turns reading. BM29 struggled to pronounce "porphyritic texture" which the textbook likened to "Rocky Road ice cream.

The classroom teacher took over the role of reading from the text and introduced a distinction between intrusive and extrusive igneous rocks. The terms were unfamiliar to the class and once again there were no sample rocks to examine. To develop the meaning of intrusive and extrusive, the teacher introduced an analogy between these terms and personality types: introverts and extroverts. He described BM29 an "extrovert" who immediately responded that he did not appreciate being "clowned with." The teacher characterized himself as an extrovert and others in the class asked to know their labels. The analogy failed to direct attention to texture patterns of rock and associate them with processes of formation. As a follow-up question the teacher asked, "What does coarse-grained mean?" had to be broken apart into a discussion of what "coarse" meant ("It goes around like a race horse," BM29). A student called out, "Rough." The teacher wrote "coarse" and "smooth" on the board and directed the class to "copy that down."

The teacher continued to pose questions about igneous rock formation. "Why do intrusive igneous rocks have larger crystals?" he asked BM11, who answered, "Because they are hot and they can't bust; the smaller ones will bust." Note the excellent imagery in this answer and the use of familiar language. Both differ from the imagery and language of the text.

Throughout this discussion the interaction between the teacher and BM29 escalated until the teacher ejected him from the class. The pattern consisted of verbal exchange (somewhat flippant), reprimand, warning, seating in isolation, and removal when the teacher said without

anger, "Grab your stuff and come here." He phoned the office and BM29 departed. The class worked in silence.

With ample time remaining in the period, the teacher announced, "Page 100, 104 due today. You have half an hour. Be sure to write down the questions. I helped you with some. The first question is, 'How are igneous rocks classified?'" Note the repetitiousness of the questions through the period and the limitation of activity to transforming notes from the board or copy from the textbook into short answers, both spoken and written.

In summary, the teacher taught in a friendly, no nonsense manner--calming, respectful, and expressive. However, defining terms dominated the lesson. There were no objects or experiences. Male students did receive the teacher's attention much more so than females, both in terms of reprimands for behavior and nominations to answer questions. The day witnessed much more instruction and introduction of content than the previous one.

Third Lesson

Several absences today signaled the beginning of a trend. On average, from this day forward, one-quarter or more of the students failed to attend class.

The teacher addressed the recurring problem of placing tacks on seats with "You guys need to get better control of yourselves. If someone puts a tack on a seat I'm going to have them suspended. Part of the problem is that all of you are responding to something that didn't pertain to you. Everybody always has to say something back if someone says something to them. Grow up a little bit. You don't have to take it forever. I'm going to hear about it sometime."

The teacher had issued a firm warning and spoke for nearly 5 minutes on a serious subject. He was very concerned about how "Everybody always has to say something back if

someone says something to them," and "all of you are responding to something that didn't pertain to you." These comments typified the teacher's brief, yet not infrequent, "sermons" on proper classroom behavior. Later, when everyone was working quietly, he took time to praise them and commented that perhaps he has not done so often enough.

Today there were definitions of cell theory, protein, and element to copy from the board--concepts unrelated to the nomenclature of rocks. The seventh graders began class by copying these same notes; the topics are harbingers of the high stakes, statewide, science benchmark exam.

Once again, students read from the textbook. The teacher called on BM27, saying, "You need to be paying attention." Next BF23 read about metamorphic rocks forming from igneous, sedimentary, or other metamorphic rocks. New terms at the end of the reading included "foliated and unfoliated," descriptors of the arrangement of mineral crystals in parallel layers or not. Once again, words about words troubled student comprehension; unfamiliar language made no reference to tangible objects.

Forty minutes into the period the teacher wrote the homework assignment on the board: page 107, questions 1-4, and worksheet question 4-4. In the text students encountered, "What is metamorphism? Name two metamorphic rocks. How does pressure change rocks?" They could find the answers to all of these questions in the 2 pages of reading just completed together as a class.

Meanwhile the teacher wrote on the board notes to use to answer the homework questions. His notes described igneous rock texture (glassy, fine-grained, coarse-grained, and porphyritic).

WM19 expressed his views to the observer during the last 15 minutes of class. He was earning an F. WM19 characterized himself as someone who "liked to do things: experiments, play, not sit and learn for a long period of time." He enjoyed dance, language arts, and social studies. "I'm just a kid," he said, "And I don't want to copy definitions all day." WM19 rarely attended class during the next 6 weeks. His reflections about how to improve science instruction were provocative. However, should policy makers take seriously advice from a 13-year-old, F student who cuts class? Yes.

Fourth Lesson

The "on board" routine started the period again: questions from the text due today, worksheet packet due next Monday. The teacher announced that his wallet was missing and offered $20.00 for its return. He added that he could not rent a video for the class without his video rental card. He has promised a video if the class behaves well for next Monday's substitute.

Someone tossed an object and disruptive behavior ensued. Students blamed each other and several became quite vocal. CT demanded to know the culprit. "If someone lies to me they will be suspended." The teacher pointed out the presence of another observer in the room able to watch for misbehavior, thus compromising the neutral status of the researcher. For the first time, he displayed anger. "Why are people talking when I am?"

Moving along, the teacher, in exasperation, reminded the class that he had given them class time plus a full week to finish the homework assignment. He moved from desk to desk to check homework while students continued to talk about the throwing incident and determine

fault. He ended this talk with, "I'm willing to drop the whole thing. Next time, if I find out who did it, you're going to get suspended. I'm dropping it."

Nearly 50% of the students came to class without their textbooks this day; it is February and daily use of the textbook has been the standard routine for some time. Study has progressed from the rock cycle to plate tectonics.

"Stop what you are doing for a second and look up here." The teacher had drawn a diagram of a mid-ocean ridge spreading center in order to help students solve a problem on the worksheet. "You guys remember what magma is? . . . You have oceanic crust. It grows both ways . . . As it travels the crust over here is going to be older . . . You need to find the mid-ocean ridge. We'll kind of go through the first one step by step."

This exercise required students to interpret a diagram, make a measurement, complete a conversion, carry out a calculation, and solve a problem: determine the age of oceanic crust presuming a uniform spreading rate from a mid-oceanic ridge. (The diagram depicted the Atlantic Ocean floor. Lines traced rock of equal age along a north-south trend, labeled to give ages in millions of years.) "The rate at which sections of ocean floor are moving away from the mid-Atlantic ridge can be calculated by dividing the distance traveled by the age," read the teacher from the directions at the bottom of the page.

"Someone pick one of those lines. I'm going to measure the distance in mm from the mid-Atlantic Ridge to that line (1 mm = 65 km). . . . Take 23 and multiply by 65. How far is it from the mid-ocean ridge to that line? It's right here. . . . For answer number one, you can put down 1495 km, but it's more important that you know how I got that." The teacher instructed the class to add 5 zeroes to express the answer in cm.

Class turned noisy as they began to work on this problem. Very few worked on the work. A quick circulation of the room found no one engaged. Students asked for the answer; they were not prepared to carry out the measurement and calculation. The task was to measure in mm from ridge to dated magma several different isochrons away, multiply by 65 to convert to km, convert km to cm by adding 5 zeroes, then divide by age in years to give spreading rate in cm/yr. Regrettably, student questions and performance suggested little or no comprehension of either the procedure or the concepts. The exercise represented a dramatic departure away from rote learning and emphasis on vocabulary toward problem solving and application of quantitative reasoning.

Students, however, resisted the challenge and attempted to find ways of obtaining the right answer without working through the steps of the problem independently. They found the style, approach, and cognitive demand of the exercise unfamiliar and, for the most part, they exercised a veto. Nevertheless, the efforts of the teacher to assist them as he moved through the room took effect. The observation notes recorded the following:

> 3:25. CT move to another table group to help 2 BM. Back table starts to work on the problems. Room continues to be noisy. At a center table female students work on the calculations, but very slowly. One WM at back table is working through the sheet using his calculator. At the other back table, 2 BMs are now working on the calculations. At middle, side table the 3 females are doing nothing. WF has her head down. 2 BF are talking; one spinning her ruler. Several female students are working on writing answers due today.

3:35. CT reviews grade book entries with WM. BM at back has completed calculations. His BM friend is now copying the answers and the calculations. Room becomes very loud as end of period approaches.

3:40. "I need you to stop talking for a second. A lot of people did a decent job getting their work done today. I still want you to be courteous, quiet, and cooperative for the substitute. This paper that you are doing today, I want you to attach it to the papers the substitute gave you on Tuesday. Chairs up on desks. "Make sure I get those rulers back!"

Prospects for closing the achievement gap in science appear to diminish in direct proportion to student inability to succeed in solving problems of this nature. In the example there is an invitation for intervention in response to a mix of promise and disappointment.

Fifth Lesson

Eighteen out of thirty students attended class. Management problems vanished and many students responded to questions. LF11, BF18, BF06, BF21, and WF07 all participated. So did BM04. With dominant personalities missing, different students answered questions and female students played a major role in class. At the start of class, the teacher offered praise: "I actually wanted to comment that this class recently is doing a lot better."

To copy from the screen were definitions of plate boundaries: convergent, divergent, strike slip. "Who's not done copying this down?" asked the teacher.

Several minutes of triadic dialogue began with "What is the continental drift theory?" For each question, students found an answer already written on the board. After students had answered several questions, the teacher asked, "If I turn this off, how many of you can answer

those questions?" He turned off the overhead projector and repeated the same questions as before, beginning with "What is the theory of Continental Drift?" WF07 responded, "When the continents are moving apart."

"There are 3 kinds of boundaries. What are they?" asked the teacher, who repeated the question and finally answered it himself. His next set of questions came from the textbook. However, 50% of the class neglected to bring books. "You're leaving me no choice. I am going to have to start writing detentions."

The teacher identified the San Andreas Fault as a strike slip boundary. He directed the class's attention to figures in the text with questions such as, "Where does it look like most of the earthquakes are happening? Where do you think plate boundaries are?" Students called out answers.

Students wished to know if Alfred Wegener became rich as a result of his theory. They expressed interest in the human side of his struggles to win acceptance for his theory among geologists who were skeptical of his meteorologist credentials. The teacher took little advantage of this opportunity to examine the subject from the point of human interest.

After a break, the teacher reviewed the questions once again, coaching them to succeed on the forthcoming chapter test. BF18 repeatedly responded correctly.

"What is glossopteris?" asked the teacher, to which BM06 responded, "I know what it is. It's a continental drift." The teacher, correcting him, said, "No, it's a fossil of a seed."

"It's a seed?" asked a surprised BM06. Moments later he explained that plates move "parallel" in a strike slip fault. "Why do plates move?" the teacher continued. WM13 suggested, "Because lava moves in currents."

Low attendance accompanied the noteworthy success of teacher-student dialogue in Lesson 5. Students also succeeded in interpreting diagrams that resembled familiar maps. BM06 offered thoughtful responses and the teacher prompted these by asking more "why" questions than in other lessons (in part because the plate theory being studied was intended as an explanatory framework providing answers to why questions). In the last exchange of the day the teacher asked, "Why would an earthquake occur at a mid-oceanic ridge?" to which BM06 responded, "Because it is spreading. When they are moving they got hooks and the hooks connect." The teacher elaborated upon this image of "hooks" explaining that ridges broke apart into many small strike slip faults. In this exchange the teacher successfully bridged between student language and imagery and the formal discourse of science. Regrettably, the lesson never turned to the example of plate boundaries close to the school. It favored the "universal and abstract" curriculum in science over local problems, examples, and issues (seismic safety in school buildings, for example).

Sixth Lesson

The teacher announced that Big Daddy would be shown for good behavior while the substitute was in charge (movie on Friday; test over Chapter 3 on Tuesday). In order to prepare for the test and reinforce student learning, the teacher had decided to review plate tectonics using a different text. This day students opened the "orange books" from MacMillan Earth Science. He wrote on the board at the front of the class:

> HOW WELL CAN YOU ANSWER ANOTHER BOOK'S QUESTION IN EARTH SCIENCE? WRITE THE ANSWERS ONLY IN COMPLETE SENTENCES.
> Pg. 184 #1
> Pg. 296 #1

Pg. 300 #1
Then look at the pictures on page 305. How many of the questions on 305 could you answer?
Define as many terms as you can on page 184. Also define strike slip boundary, convergent boundary, divergent boundary.
Extra credit: Draw a detailed, colored picture of a convergent or a divergent plate boundary.

The class had the period to work on this assignment. The teacher shared an example of creative work from another section (colorful drawings depicting plate boundaries for extra credit). No one read aloud during Lesson 5. In order to drill the class on the nomenclature of plate tectonics, the teacher assigned the task of answering questions in a text different from the one normally used. The vocabulary and concepts were identical to the ones already studied. The teacher believed that finding the same concepts and definitions in slightly altered form and phrasing in this different text would reinforce their knowledge and make them better prepared to answer questions on the state-mandated Eighth Grade Benchmarks exam in science.

Seventh Lesson

From the observation notes:

BM14, "I'm tired of all the Fs in my life." He says he wants to get out of this class. CT comes over; removes pick from BM14's hair. CT moves on. BM14 tears up his answer sheet. "Man, this is dumb. I might as well stop . . . " BM14 has a 43. CT asks, "Did you do all of your homework? Please put that magazine down."
Class is patient; students talk quietly with each other waiting for instruction to begin. A few read from their texts as the CT returns the tests (machine scorable answer forms). Highest grade was an 88. . . . CT, "You guys complain about your scores, but you don't do the work. . . . I acknowledge those tests were difficult."
2:50. "Listen up. Part of the reason the tests are difficult is the way I do homework.

The teacher explained that homework points constitute half of the course grade. Thus, students who have consistently completed their homework have laid a foundation for earning a good grade. If they do well on the exam, they earn an A. If they do poorly on the exam, they can still pass or earn a C.

A new instructional cycle began with Lesson 7 on the topic of soil. Students have received worksheet packets for the new chapter. The teacher introduced the weathering section of the text by saying that it included many of the answers needed to complete the packets. The text introduced students to the concepts of chemical and mechanical weathering.

LM02 sat without a book or packet. BM29 left the room, flicking the lights on and off. BM27 had no book and paid little attention; he eventually obtained a book. The situation felt familiar; then an unexpected exchange took place.

The teacher asked, "Are there any questions?" BM25 wished to know, "What is the process that changes the chemical make-up of rocks?" During the course of recording several dozen teacher-student exchanges, students asked the teacher a question no more than 3 times.

The teacher carefully answered BM25. "There are a few different ones that can occur. Oxidation is one. On page 113, BM25, it talks about water and carbonic acid." Several moments later the teacher visited BM25. "Did I answer that question for you? Chemical weathering can happen a number of different ways . . . " A month ago the school had suspended BM25. This class he was an exemplary student--a bit of promise on a day that deeply disappointed not only BM14 but also the teacher. Neither felt good about the score of 43%. And there were no samples of weathered rocks for BM25 to examine.

Clearly, the test results disappointed the teacher. He changed the format to focus more on key points and displayed these on the board or screen. He stressed work habits. He began class by checking with each student individually on homework. He tried using study questions from a text other than the adopted one in order to have students think about the concepts from a slightly different perspective. Still, the scores on the plate tectonics exam disappointed him. Poor attendance frustrated him as well and he was anxious to have his students achieve more.

The classroom teacher has devoted extracurricular time to leading a chapter of MESA and the school's team his team captured several honors at a recent competition. Why was regular class so unlike MESA? Might it become more so?

Eighth Lesson/Last Observation

Attendance was 16. The period started with chasing and chaos. Several students arrived late; the teacher closed and locked the door to exclude tardy arrivals. BM25 did not bring his book (now a chronic problem). The teacher refused to let him return to his locker; the confrontation escalated and the teacher sent BM25 to the office.

The teacher spoke, "Quiet down please. I don't mind if you are going to be talking, but you need to be working. If you're not doing anything when I come around, I'm going to give you a warning because you're not following directions." Eventually all were silent.

The teacher directed attention to the notes he had projected on the screen reviewing mechanical weathering and exfoliation as caused by heating and cooling. He explained, "Exfoliation is when a rock splits in layers. The sun shines and heats up the rock on the outside but not the inside. In the night it cools . . . expands and contracts over and over . . . gets weak

and cracks off." He also shared a diagram of soil horizons from top to bottom: A topsoil, B sub-soil, C parent rock, D bedrock in mature soil profile ("one that has had time to form").

The teacher announced a forthcoming test and made the review for it very explicit. The teacher tried hard to help students score high. He covered vocabulary extensively, discussed some examples, yet shared no objects. The teacher had done everything he believed he could to prepare this class to score well on the next exam. In addition he had emphasized the need to use class time well, complete homework, and develop good study habits. He told the class that doing so will result in high grades. In addition, by provided them with notes that answered the test questions and permitted them to consult notes during the test. Sincere and heroic, he has all but done all the work for them.

Patterns of Interaction

In this case study based on sixteen visits spanning three months by one observer trained as a science educator no episodes of laboratory instruction were observed in either the seventh or eighth grade. The teacher reported conducting one investigation in each class (lighting a bulb in physical science and using food coloring to observe convection currents in earth science). Reading from the textbook, answering chapter questions, completing worksheet packets from the publisher, or reviewing for a test dominated the use of time. The teacher occasionally conducted a demonstration or shared a prop (for example, he lighted a bulb with a wire and battery and passed a credit card around the room that had a holographic logo).

Classes began by taking attendance (which declined precipitously in eighth grade to less than 70%), followed by checking for completion of homework. On a typical day and for up to the first 30 minutes of class, the teacher moved from desk to desk, grade book open, recording

and rating homework completion for each student. This procedure guaranteed each student a moment of personal contact with the teacher on most days. However, a homework completion rate of 50% was the norm. The school operated under a block schedule; thus class met every other day for 90 minutes.

Often the teacher granted the class a "break" as a reward. Nearly every class ended with at least fifteen minutes of time to begin work on homework, typically four or five questions to answer based upon two or three pages from the textbook. No visit recorded more than a 45-minute episode of teacher-directed instruction. Typically, the teacher led the class in answering questions projected onto the screen, found in the textbook, or taken from a worksheet for an average of approximately 30 minutes before transitioning to seatwork or a break.

Rote learning, driven by concern for short, correct answers—often to questions calling upon students to define terms—predominated over, but did not exclude, applying concepts to examples (e.g., of uses of different wavelengths of electromagnetic radiation in medicine) and developing analogies (e.g., between introverted and extroverted personalities and intrusive and extrusive igneous rocks).

Review sessions had the most extensive episodes of teacher-directed question and answer dialogue. Very rarely (almost never) did students initiate questions or did the lesson structure encourage open discussion. Said the instructor during one such exchange, "I love your questions, but we have to get through this stuff." The discouragement of student questions was more implicit than overt; each time a question was asked, the teacher paid attention to it and responded positively to the student asking the question.

Teacher-student dialogue, rote learning, and the use of target students characterized the instructional interaction. The teacher issued reprimands, warnings, and detentions quickly and without anger to individuals and delivered "sermonettes" both scolding and praising the work habits of the class in general on numerous occasions. After factoring out the consequence for behavior for one particular Black male, students in seventh grade received reprimands and warnings at indistinguishable rates. So, too, in the eighth grade was a single Black male the recipient of one-third of all of the teacher's disciplinary actions.

Three Black males in eighth grade received multiple reprimands and warnings; one of these was suspended. The other two often participated in class in a positive manner and received nominations to answer questions on a regular basis. One Black male's behavior—"up and down" in the words of the teacher—alternated between attentive, intelligent responses and disruptive, attention garnering remarks. Ogbu classifies such behavior as a form of camouflage: "By acting foolishly, the Black youth satisfies the peer expectation that he or she is not very serious about school [yet] . . . takes schoolwork seriously when he is away from his peers and often does well in school" (Ogbu, 1991, p. 163).

Ogbu's attribution of camouflage behavior to Black, adolescent culture has prompted controversy and met with deep skepticism. Clownish behavior that entertains peers and may mask taking schoolwork seriously must be understood with the context of adolescent development, regardless of cultural background. Interview data from the PEASS project, for example, give no credence to the notion that Black adolescent school culture devalues learning any more or less than other adolescents.

The seventh grade Black male who received a disproportionate share of reprimands and warnings did voice a clear intent to attend a Black college in the future despite behavior suggesting little attention to schoolwork. He also answered in-class questions successfully (e.g., "What type of light gives off heat?" to which he first responded, "Fire," then added, "Incandescent!").

In eighth grade, the observations recorded only one instance of a White student (female) receiving a warning. All other such reprimands were addressed to Black students. Interestingly, the teacher described the seventh graders as his "best class" and the eighth graders as "extremely troublesome all year." On more than one day, less than 50% of the students came to class with their textbooks, to the teacher's deep dismay.

In terms of patterns of discourse, occasionally a student response or question revealed imagery about the topic of discussion quite different from the language of the text: intrusive igneous rocks have large crystals "because they can't bust," according to an eighth grade, Black, male student. Analogies often failed to contribute to understanding explanations; the "introvert-extrovert" comparison of personality types with intrusive and extrusive igneous rock formation even ignited a confrontation between the teacher and a different Black male student whom the teacher described as an example of an "extrovert." The lack of tangible meaning (for example, "coherent" light in lasers) or conflict between everyday usage and jargon in science (i.e., "colors and pigments"—pigments "subtracting" light and colors being "additive") made language unfamiliar. Limited teacher knowledge in science ("Light waves are not just carrying energy; they are also carrying particles," was his way of explaining wave-particle duality and introducing the concept of photons) further contributed to episodes of confusion and curtailed the discussion of ideas.

In addition, the teacher tended to convey a naïve, inductivist conception of the nature of science: "Science is just about observations. . . . That's all it is—you write down your observation, you're making guesses about your observations." This view accorded insufficient attention to the task of forming concepts. At the same time, it was inconsistent with the instructional approach; students seldom made observations.

Subsequent sections elaborate upon these patterns, beginning and ending with attention to patterns of dialogue.

Discourse

Lemke (1990) analyzed the discourse of science classrooms and laboratories and found that "a simple two-part Question-Answer structure" (p. 8) failed to characterize the most pervasive pattern. Instead, a multi-part "Triadic Dialogue" dominated teacher-student interaction structured as follows (the brackets indicating optional or frequently omitted segments):

[Teacher Preparation]

Teacher Question

[Teacher Call for Bids (Silent)]

[Student Bid to Answer (Hand)]

[Teacher Nomination]

Student Answer

Teacher Evaluation

[Teacher Elaboration]

Figure 1

Students learn to recognize the context and signals that preface a question from the teacher to the class. The teacher poses the question and may pause silently before calling on someone to answer; the nomination, at times, may precede the question and the teacher may choose to break the pattern by accepting call outs. The teacher has several choices to make after a student has answered: praise the response, restate the response with modification, correct the response, disapprove of the response, accept another bid, or elaborate upon the response.

Nearly all teacher-student dialogues observed conformed to Lemke's triadic structure. The teacher ended a dialogue with brief praise and never with criticism for a wrong answer. Typically, he engaged in "teacher monologue" (Lemke, 1990) to modify, extend, or elaborate upon a student response that he felt was misleading or incomplete.

The teacher depended heavily upon chapter questions from the textbook and packets of study questions from the publisher. He asked questions in the form, "What is/are _______?" most often, and occasionally a question prefaced with "why." Attentive students realized that answers could be found on the screen or board, in their notes, or within 2 to 3 pages of text.

The teacher repeated the same question in many lessons, expecting right answers from multiple students. He cued them as to which questions would also appear on the next chapter test. On one occasion, he had students read answers from the projection screen, then turned off the overhead projector and repeated the same questions. Typically, before students started to work on homework packets, the teacher guided them through the information they would need.

Student proficiency in reading worried the teacher. Often he called upon a few students to read from the textbook in class. Reading scores were a school wide concern. Recall that nearly

two-thirds of the eighth grade students at this school tested below grade level benchmark defined by the state.

Students seldom had a chance to express their thinking or observations according to the imagery of their everyday, personal language. Attempts to do so were notable: crystals "busting" rocks with "hooks." Examples of the "human face of science"--objections to Wegener's Theory of Continental Drift, applications of electromagnetic radiation to medicine, for example--captured imagination and promoted discussion.

Except for the example of using maps to find plate boundaries, students struggled to interpret diagrams. Not knowing the concept or relationship being represented and unfamiliar with the representational scheme, they had little success using diagrams to determine answers to chapter questions. Progress in science depends upon intelligent construction of representations as much as upon thoughtful empirical work. Diagrams merit classification as a form of discourse, one that does not readily match student imagery.

The textbook authors and classroom teacher employed analogies in order to develop concepts. These often proved unhelpful (personalities and rock types, shooting arrows and photon energy level, sanding wood and erosion, even rock formation as a cycle).

Scientific terms lacked tangible meaning. They did not refer to physical events or features of real objects. Instead, students learned words about words, aided by diagrams and illustrations in the textbook. The abstract sense of meaning crucial to distinctions in science escaped their comprehension. Sometimes terms held everyday meaning mismatched with science (the example of light as colors and pigments). Sometimes terms were completely alien to students: porphyritic texture, coherent light, for example

Discipline

Table 1 depicts the frequency of teacher reprimands to individual students. Reprimands ranged from asking a student to dispose of gum to assigning detention. These data do not include the events or interactions leading to the suspension of a Black male in the eighth grade. BM11, seventh grade, was sent to the office on one occasion. On another he was assigned to a desk in the corner of the room.

Inspection of the raw data reveals a strong pattern: in each class the disruptive behavior of a single Black male received a disproportionate—and necessary—share of the teacher's disciplinary actions. Although in eighth grade only 1 non-Black student received a reprimand during the periods of observation, 5 different Black females received admonishments. Several of these occurred during a single class; the disruption was not serious—simply talking too loud.

In most respects these tallies are low. Classroom misbehavior did not overwhelm the teacher. He did admonish each class 3 or 4 times a period regarding work habits, noise levels, and movement. He used explicit rewards to change behavior: videos for behaving well for a substitute, 6 minute breaks for staying on task during class period, and popcorn parties and outdoor lessons for overall success.

A small slight had the potential to trigger an escalation of confrontational behavior. For this reason, the teacher adhered to a high rate of nearly instant warnings for misbehavior.

One afternoon BM11, seventh grader, escalated a confrontation with a substitute teacher. He overturned a desk, turned off the class lights, and engaged in several other disruptive acts. All of these began when he attempted to adjust the position of an overhead transparency so that he could copy a part that was not being projected. The episode merits scrutiny:

Table 1
Reprimands and Warnings from the Classroom Teacher
Observed During 8 Classroom Visits

		Grade 7 Physical Science			Grade 8 Earth/Space Science		
Group	Sex	Enrollment	Reprimands	Different Individuals	Enrollment	Reprimands	Individuals
Black	Male	5	11	3 (8 BM11)	6	13	5 (6 BM29)
Black	Female	7	3	3	8	5	5
Latino	Male	2	2	1	1	0	*
Latino	Female	4	0	*	2	0	*
Asian	Male	1	0	*	1	0	*
Asian	Female	0	*	*	1	0	*
Native Amer.	Male	1	0	*	0	*	*
Native Amer.	Female	0	*	*	0	*	*
Pacific Island	Male	1	0	*	0	*	*
PacifIs land	Female	0	*	*	0	*	*
White	Male	3	3	3	5	0	*
White	Female	7	6	5	5	1	1
Total	Male	13	16	7	13	13	5
Total	Female	18	9	8	16	6	5
Total		31	25	16	29	19	10

* No Data

"This is my second day," remarked BM11. The physical science class started with instructions to copy the definitions of cell theory, protein, and element projected on the screen. BM11 tried to lower the notes in order to see them better; the substitute told him to return to his desk. In response he uttered, "Man I ain't writing that thing." A progression of drumming, slamming drawers, taunting a female student, throwing an eraser, and standing on a desk followed. The substitute interceded calmly. Moments later the student left the room.

After tending to some other horseplay, the substitute said, "Let me give you some information that will help you with this worksheet. You can read pages 82-85."

This vignette captures a common pattern of classroom work: copying definitions (or notes), and then working on questions from the text. The text questions ask students to define wave, define particle, and explain an analogy between arrows and energy levels. Material with little potential to engage students meaningfully—a standard pattern of rote learning—carries implications for how teacher and students will interact. In effect, even modest rates of rewards and threats of punishment produce both docility and rebellion. This misconceived rigor inherent in the premium placed upon learning definitions does nothing other than debilitate both teaching and learning. And this was BM11's second day of middle school science.

The teacher practiced classroom management with good success. Students knew the rules and consequences and accepted the teacher's authority as fair. He could enter a chaotic room and call the class to order in just a few moments without shouting and also allow socializing to run its course during a break. There was genuine affection between the class and the teacher, well earned on his part.

Rote Learning

The "good" students strove to complete, not comprehend, their work. The portrait of the eighth grade, earth science lessons overwhelmingly underscored the prevalence of rote learning. Rigor misconceived as learning vocabulary propelled the curriculum into a downward spiral of note taking and chapter question review. Students rarely answered why, made inferences, solved problems, or interpreted data.

Most alarmingly, students addicted to "right answer" science worked hardest to transform tasks into rote exercises when the content was the most abstract. The effort to learn by rote rose as abstract complexities multiplied. When asked to reason by analogy and find correspondences between shooting arrows and shining light, students pressured to know where to find the answer in the text. They also persuaded the teacher to tell them what parts of the notes on the board to copy in order to answer difficult questions about the wave-particle duality of light. When presented the task of calculating spreading rates, most tuned out, a few did the calculations, and several did not hesitate to copy answers from their peers.

Teacher confusion about abstract concepts compounded this problem. In a lesson comparing virtual images to real ones, attention turned to the example of a motion picture. Because the light was reflected from the screen, the picture was labeled "virtual." Yet students had good reasons to classify the image as "real." Concerned for labeling the example correctly crowded out consideration of what happens to light as it encounters different surfaces. Instead of an "event-sense" of the topic students learned only "word-sense." They did not play with mirrors, either. Attention to student language and imagery in the context of paying attention to "what physically happens" may provide a meaningful antidote to rote learning.

Implications and Recommendations

For a century educators have wrestled with the implication at the heart of John Dewey's educational philosophizing: the abstraction of meaning from experience and the use of meaning to re-organize experience in another context. As argued at the outset of this essay, school science isolates science concepts from the context of inquiry at psychological peril to the student. The most basic implication is to introduce science concepts in the context of direct experience of

events and objects. Let words have a chance to make reference to real things. Let us refer to this goal as "cognitively responsive" instruction.

In doing so, care must be given to keeping language from becoming coercive and authoritarian. Scientific discourse that prioritizes formal terms void of tangible meaning and bulldozes through student imagery and expression, only alienates students from experiencing phenomena and having any good reason to order their experiences scientifically. From the point of view of a scientific discipline, knowledge serves a useful and compelling purpose. Week after week of students experiencing purpose as nothing more than a quest to learn vocabulary succeeds in perpetrating a fraudulent representation of science. Certainly, the centrality of inquiry and the irreducibility of inquiry to process described cogently in the National Science Education Standards (National Research Council (NRC), 1996) speaks to this point. Parents and activists have demanded that their children be taught properly. The NRC agrees.

Psychologizing the curriculum, attention to tangible meaning, honoring student-centered discourse, and teaching science within a purposeful context suggest the meaning of "cognitively responsive" teaching. Closing the Black-White achievement gap demands something more, something else: culturally responsive pedagogy. To update Dewey is to wed cognitively responsive and culturally responsive pedagogy. From a Dewey perspective, teachers attend to making the ideas of science alive in the context of individual experience. Adding the challenge to teach in a culturally responsive fashion means examining the disciplines of science from the perspective of the cultural identity of the child and his or her community.

In essence, dual alienation marginalizes students and discourse patterns enforce this alienation. They are alienated cognitively from the application of personal experience to the

challenge of learning and alienated culturally from the resources of their community as the attempt to interpret meaning.

Unfortunately, this analysis has silenced the Ogbu's question about the role of community forces and the cultural practices developed by minorities in response to the circumstances of their disempowerment. The analysis has skirted the issue of "oppositional behavior" and immigrant belief in the "instrumentality" of schooling. However, the union of cultural and cognitive pedagogical responses promises to redress this imbalance.

Ogbu, clearly, never intended for teachers to treat students as anything other than valued individuals. His primary advice to teachers is to build trust. By alerting teachers to the problem of dual alienation--cognitive and cultural--they are better prepared to improve their teaching and become caring adults in charge of beloved children.

Is the "Cycle" Really Safe?

The observed science curricula, and the manner of their implementation, have little potential to "close the gap" in achievement. The fault lies not with the teacher nor with the adopted materials, but (1) in the pattern of expectations and habits (including those of the students) that anchor daily routines and (2) in the lack of imaginative vision at the systemic level about how to operate differently. What to cover—driven by testing directives—has co-opted teacher discretion. The premium placed on recalling definitions and on demonstrating comprehension by recognizing examples of a concept have substituted for the development--and progressive differentiation--of concepts in reference to experiencing and interpreting the occurrence of physical events.

This case illustrates a classic problem for the education of poor minority youth in science: lowered expectations responding to the demands for very structured classroom management routines and the persistence of low level reading ability. Reform efforts that place a premium on rote learning as a way of demonstrating literacy in science worsen the problem. The pattern of interaction reinforces itself: interesting content and complex, hands on activities present the teacher with overwhelming management problems; therefore, the teacher reduces the complexity and omits the hands-on activities. The scoring and record keeping required to monitor the progress of at-risk learners and the accumulation of paper resulting from print-bound exercises subtract time from planning for interesting classes. Low levels of attention follow from uninteresting content; low levels of performance prompt the teacher to structure the class in increasingly less challenging ways; student attention declines, attendance drops; the teacher applies pressure to students to discipline themselves to complete homework, study review questions, answer chapter questions. More and more class time is spent talking about work habits. Only a small number of students find the topics interesting or that the content connects to personal experience. Those that in fact engage in study--"good" students--become models for others. These others then mock the good students or enjoy labeling themselves and many of their peers as poor students who are "not good in science," with or without the added distraction of desire to avoid "being white." The cycle becomes safe and persistent, and remains, of course, ineffective.

The Gowin quotation (1986) appearing earlier in this essay ends with the assertion that the cycle of debilitating rigor is popular and therefore safe. His assertion captures an element of truth yet voices a profound error. For those at risk of dual alienation, the debilitating cycle has a

differential and doubly damaging impact. The debilitating cycle of misconceived rigor, the failure to teach responsively from both a cognitive and cultural perspective, is decidedly unsafe. Instead, it embodies a disturbingly dangerous form of violence that diminishes the soul of this nation, does harm to both spirit and intellect, impoverishes the future of innocent students, and saddens the hearts of heroic teachers. Rhetorically embellished, that is exactly what the Black-White achievement gap means.

Recommendations Regarding Culturally Responsive Pedagogy

The performance patterns of African American students suggest that they experience cultural conflict in the learning environment and that this conflict impedes learning. The disparity of achievement in science may then stem from the interaction of this cultural conflict with the obstacles to learning presented by the rhetorical patterns and conceptual structures of science. Through interaction in the science classroom, cultural conflict and rhetorical style appear to magnify the alienating aspects of schooling resulting from oppositional attitudes or beliefs.

Various theoretical approaches have been used in the study of the learning experiences in classrooms containing students from diverse cultural backgrounds where cultural conflict may occur and where a cultural disconnect between students and school may adversely impact student achievement (e.g., the construct of "cultural congruence" in the research of Au & Kawakami, 1994). The research questions in this study were designed to establish an empirical basis for cultural congruence and other theoretical constructs used in researching multicultural contexts. The underlying premise of cultural congruence is that ways can be found to align the culture of the student and that of the school in ways that significantly reduce the conflict and therefore enhance learning. The quest for such positive alignment of cultures has to include a close

examination of the potential impact of particular instructional strategies on the academic achievement of students from diverse backgrounds.

Hollins, Smiler, and Spencer (1994) have suggested that inquiry-based or participatory problem-solving instructional approaches are more consonant with the learning and socialization patterns of African American students than are rote-memory ones. Results from this study indicate that rote or mainly information delivery instructional strategies may impact the learning of African American students in especially adverse ways.

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STORIES FROM THE FIELD: CHALLENGES OF SCIENCE TEACHING AND LEARNING THROUGH INTERDISCIPLINARY APPROACHES

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Historical tendencies in elementary schooling are limited school science or textbook-based science when it is taught (Akerson & Flanigan, 2000). Currently, as a response to the recent language literacy emphasis and the advent of school report cards in the states such as Colorado and California, district level and school-based administrations are sending additional messages to teachers about the relative value of learning in curriculum areas. In Colorado, for example, the results on statewide assessments which solely evaluate language and mathematics achievement at the elementary level are the basis for schools' report card ratings. To raise scores on these tests, elementary teachers are being told to either stop teaching science or to ignore the science content standards in their grade level curriculum. In California, many elementary schools have gotten involved in "open court," a prescribed curriculum for enhancing reading and writing skills that leave any time for science teaching and learning. For the elementary teacher who lacks in science preparation and confidence this prescribed curriculum might be considered a blessing. It has been shown that elementary teachers who lack in confidence in their abilities to teach science and/or content knowledge tend to avoid spending time on science (Abell & Roth, 1992; Czerniak & Lumpe, 1996; Smith & Neale, 1989). In the circumstances previously described science learning may become infused solely through an interdisciplinary approach to curriculum that stresses language and math literacy development.

In California some middle schools are organized around interdisciplinary teams and are taking a thematic approach to teaching and learning. Magnet schools at all levels are almost totally organized around themes and interdisciplinary teaching groups teaching the same students. At the high school level some schools are using an integrated sciences approach (e.g., Humanitas). These situations are being observed in the schools in which the emergency permit teachers [EPTs] enrolled in the teacher education program at a university in Southern California. EPTs comprise a relatively new category of teachers who are simultaneously teaching and pursuing course work needed for teacher certification.

Teachers' beliefs systems, judgments and decisions in classroom practice are grounded in their life histories and experiences, both personal and educational (Connelly & Clandinin, 1995; Goodson, 1992; Prawat, 1992). This research-based assertion lends toward the speculation that teachers' experiences with, understandings of and attitudes toward using an interdisciplinary approach could play a critical role in their and their students' learning of science (Akerson & Flanigan, 2000). Given that today's teachers do teach in these contexts, it behooves science teacher education faculty to consider the possibility of reframing science teacher education to encompass interdisciplinary orientations. Without formal opportunities for learning science and learning to teach science in which interdisciplinary approaches have been modeled, teachers have less experience with experiencing the challenges of interdisciplinary teaching (Hillman, Bottomley, Raisner & Malin, 2000), particularly if scientific inquiry is to be an integral aspect of students' science learning. Nor may teachers have been prepared for team teaching roles that can be affiliated with interdisciplinary approaches to school learning. What dilemmas may be associated with such circumstances?

Brain-based research and recent ideas about intelligence (Armstrong, 2000; Sprenger, 1999) support the use of interdisciplinary approaches in education. The middle level teacher education literature advocates for an interdisciplinary perspective to curriculum design and teaching/learning (Barab & Landa, 1997; Beane, 1991; Drake, 1991). According to the findings of studies situated at the college/university level (e.g., Akerson & Flanigan, 2000); Akins & Akerson, 2000; Cherif & Gialamus, 2000; Saam, 2000), it makes sense to entertain this possibility.

We, the authors of this paper, believe that science teacher educators have a responsibility to prepare teachers for teaching in classrooms where multiple literacies tug at a teacher's attention. We need to heighten teachers' awareness of the dilemmas that can arise when providing for or advocating science learning in these contexts. We need to provide prospective, EPTs and practicing teachers with experiences that help them find solutions to these dilemmas. The purpose of this paper is to examine and discuss emergent dilemmas related to the use of interdisciplinary approaches as a vehicle for enhancing teachers' understanding of the nature of science, their teaching of science, and issues related to collaboration. The dilemmas will be presented as composite stories (Connelly & Clandinin, 1988; Barone, 1990; Manen, 1990) in order to provide the reader with the richness and complexity of the situation at hand, and to invite the reader to participate in a disciplined inquiry process.

Learning from the Literature: Theoretical Background on Interdisciplinary Curriculum

Curriculum integration is a revitalized educational idea (Carter & Mason, 1997; Grossman, Wineburg, & Beers, 2000) for which a variety of typologies have been proposed (Clarke & Agne, 1997; Fogarty, 1991; Jacobs, 1989; Martinello & Cook, 2000; Mauer, 1994; Post, Ellis, Humphreys, & Buggey, 1997; Roberts & Kellough, 2000). Albeit the typologies

differ in their taxonomy, they share the basic idea that interdisciplinary curriculum design can be described by a continuum of possibilities that ranges from a discipline-based focus to a holistic focus on an idea, issue or a learner's question.

Jacobs (1989) defined the construct, 'interdisciplinary' as "a knowledge view and curriculum approach that consciously applies methodology and language from more than one discipline to examine a central theme, issue, problem, topic, or experience" (p.8). According to Jacobs, teaming is an integral element of this perspective of interdisciplinary curriculum. Tchudi and Lafer (1996) underlined the potential of an interdisciplinary curriculum to amplify the effect of different disciplines. In their proposed model, the S^2, the effect of structure, that is the guidelines and mandated concepts for each discipline, is multiplied by spontaneity, that is creativity. This model requires correlated resources, integrated classroom activities and common performance assessments between the various disciplines involved in order to ensure success. Similar ideas of teaching and learning using interdisciplinary approaches and a need for grouping were also described in Wood (2001). Wood strongly advocated for dividing "research-oriented thematic units" (p. 16) into manageable chunks to be processed by various "committees" of students.

In the field of science education, Lederman and Niess (1997) have suggested that the labels of interdisciplinary and integrated have been used synonymously as well as to distinguish between critically different curriculum and teaching models. They proffered a soup metaphor to distinguish between interdisciplinary and integrated approaches. Accordingly, an interdisciplinary approach is analogous to chicken noodle soup with its clearly distinguishable ingredients. Though connections between disciplines are made, the integrity of disciplines remains clear as value is strongly placed on the unique characteristics and distinctions among the

disciplines. An integrated approach is akin to creamy tomato soup. In an integrated curriculum, different disciplines are blurred into a seamless whole.

Despite the variety of interpretations for curriculum integration and interdisciplinary curriculum and teaching/learning, teachers and teacher educators are coming to believe they have value and merit regarding teaching and learning (Minstrell, 2000; Zoller, 2000). Zoller has advocated for an interdisciplinary approach to learning in order to ensure transfer of the higher order conceptual skills [HOCS]. Minstrell has contended that interdisciplinary inquiry leads to "intellectual pleasure and a sense of personal accomplishment" (p. 472).

The professional literature has historically focused on the merits, shortcomings, and dilemmas of interdisciplinary approaches in K-12 schooling (Beane, 1991; Carter & Mason, 1997; Pate, P.E., Homestead, E. R., & McGinnis, K. L., 1997). However studies are being reported for the tertiary level. A course developed around the topic of astrobiology explores and corrects popularly held misconceptions related to ideas such as UFOs and life in the universe (Sauterer, 2000). In Cherif and Gialamas (2000) college students created final art projects as the culminating event to synthesize and communicate what they had learned in science and mathematics courses. The projects were judged from scientific and mathematics perspectives. The science projects were evaluated based on the accuracy of scientific knowledge, art creativity, evidence of originality, and the degree of integration of the sciences and the student's major. With respect to mathematics, the projects were evaluated based on the degree of difficulty of the mathematics concepts presented, the degree of difficulty of the art project, creativity, artistic quality and presentation. Although students complained about the number of hours spent on researching and preparing their projects, they also "learned a lot from doing their projects, as well as from listening to all the presentations of their classmates' final projects" (p. 277). In

addition, students rated the final project as the second-most important reason for enrolling in additional science and mathematics courses not required for graduation.

Teachers of science, both prospective and practicing, using an interdisciplinary approach in their classrooms are also engaged in their own learning processes related to the nature of science and science teaching. What is known about what happens when they consider or use interdisciplinary approaches to science learning? This gap in the science education literature has led us to inquire about the challenges that emerge for teachers as they endeavor to enhance their scientific understanding in an interdisciplinary learning environment.

Thinking about Learning: Theoretical Foundations of the Research Process

This research has its foundation in the constructivist epistemology, according to which learning is a social process of making sense of experiences based on extant knowledge (von Glasersfeld, 1989; Tobin, Tippins, & Gallard, 1994). In an attempt to clarify the interaction between the individual and the social aspects of knowledge construction, Tobin and Tippins (1993) stated, "Knowledge is personally constructed, but is socially mediated. That is, knowledge only exists in the minds of cognizing beings, but cognizing beings only exist in a social-cultural sense" (p. 6). Thus, because of the socio-cultural aspect of knowledge construction, the context of knowledge development must be addressed. Giroux and Simon (1989) described a teacher as a transformative intellectual, an individual who encourages students to question content-related assertions, as well as established social norms. Such environments support knowledge construction through an empowering (Grundy, 1987) or liberating (Freire, 1990) atmosphere.

In our case, we analyzed interactions at the level of the interdisciplinary groups. We focussed on learning as described by social constructivism and on the process of creating teachers that belong to the " transformative intellectuals" (Giroux & Simon, 1989).

Generating the Stories: The Research Process

This research focused on two groups of teachers, both involved in interdisciplinary inquiries. Although the groups are located in two very different areas in the US (rural Colorado and urban Southern California) and are at different stages in their professional teaching careers (traditional student-teachers to 28 years of teaching experience) with diverse areas of expertise, they exhibit striking similarities in their attempts to collaborate in an interdisciplinary endeavor.

In the process of generating each story, each course or the professional development project represented a case - a bounded phenomenon, system or social unit (Merriam, 1998). The examination of each case was a study of the "particularity and complexity" of the situation with the intent to "understand its activity within important circumstances [or context]" (Stake, 1995, p. xi). In this interpretive study (Eisner & Peshkin, 1990; Erickson, 1986; Gallagher, 1991; Guba & Lincoln, 1989) investigation centered on emergent dilemmas related to the use of interdisciplinary approaches used by prospective teachers, emergency permit teachers and practicing teachers as they endeavored to enhance their understanding of the nature {and teaching} of science and the professional development of the interdisciplinary teacher.

Participant observation, video taping, examination of field notes, and examination of documents produced during the courses and during professional development project were used as the basis for understanding the interdisciplinary experiences and for generating the composite stories that communicate the emergent dilemmas in the experiences. Amassing and interpreting these materials was ongoing and concurrent throughout the teachers' involvement in the

interdisciplinary experience. Data analysis was both deliberate and systematic, as well as intuitive and informal. Systematic analysis consisted of teachers' searching for patterns within and across the field notes, videotapes, and documents. Shared and particularistic patterns were noted and served as a foundation to think about the significance of the pattern and to aid in the writing of the composite story. Patterns noted also served as a guide for reflection and action, for the teaching of the course and for the project. Intuitive and informal analysis also took place during and immediately after course and the professional development project sessions, as individuals reflected on what was happening or had happened, shared their perceptions with institution-based colleagues or each other, or planned future class or project sessions. This reflective process, namely thinking about the meaning of patterns and planning appropriate courses of action, fits with Merriam's idea of theorizing -- "thinking about one's data .... steps toward developing a theory that explains some aspect of educational practice and allows one to draw inferences about future actions" (1988, pp. 146-147). This process is also consistent with Guba and Lincoln's (1989) idea of the "hermeneutic cycle" in which emerging patterns are constantly negotiated with "stakeholders," the individuals who are placed in some way at-risk by the research activity, and peers who are not stakeholders.

The creation of composite stories is based on classic literature in the area (Barone, 1990; Connelly & Clandinin, 1988; Manen, 1990). Maanen (1988) called such stories "impressionist tales" in an attempt to recognize the artistic dimension of reporting ethnography. Like with impressionistic paintings, composite stories go beyond specific individuals and fine details that might identify a specific place and time into the creation of stories that become more generalizable and provide a foundation for educational discussions. Barone labeled this kind of

narrative invitation to engaging in education discussion as "conspirational texts." He used "conspiracy" in the sense of:

> a conversation about the relationship between present and future worlds. The reader, a historically situated self, learns from the recreated other in the text to see features of a social reality that may have gone previously unnoticed. And, if the reader, although cautious and wary, ultimately resonates with the interior vision of the text and is persuaded of its usefulness, he borrows it for his own. There is a "breathing together," a sharing of ideas and ideals for the purposes of an improved reality. This conspiracy is a plot against inadequate present conditions in favor of an emancipatory social arrangement in the future. (p. 314)

It is important to underline the fact that using stories as a tool for educational research and change is becoming increasingly popular (Ritchie & Wilson, 2000). In the field of science education, Barton and Yang (2000) emphasized the use of case study (Miguel in their case) to understand the situation of science education in an inner-city environment. Koballa and Tippins (2000) published a collection of cases for middle school and secondary science teacher education. Similarly, Howe and Nichols (2001)have published a collection of cases to be used to teach elementary teachers about the art of teaching science to young children.

<u>Learning from the Stories: Collaboration and the Importance of Honoring Diversity</u>

Both stories are set in standards-based school settings in which the teachers are held accountable for aligning what they teach to state or district standards. The idea of a standards-based movement with standards becoming the curriculum, however, is not at the forefront of these teachers' thoughts and feelings. These teachers are oriented toward developing a problem-

based/theme-based curriculum for which standards are, afterward, specified. Issues related to working together are the focus of their attention.

The first story focuses on a group of emergency permit teachers [EPTs] who have different areas of subject expertise. They represent different cultures and use different languages to communicate their observations of natural phenomena. Through their interactions they come to honor the diversity of their respective languages, with each language serving as a window of insight into the EPTs' personal culture. The EPTs teach in schools in a southern California metropolis and are concurrently engaged in an inquiry process in their interdisciplinary methods course.

In the second story, a team of teachers and a prospective teacher, who have a range of teaching experiences, wrestle with personal challenges in order to work collaboratively to create a meaningful interdisciplinary, inquiry-oriented learning experience for their first and sixth grade students. They teach in a school in a mountainous rural area in Colorado and are involved in an Eisenhower-funded professional development grant project that is modeling and promoting interdisciplinary approaches to science and math learning.

Story 1: It's a Bird of Paradise

In the interdisciplinary methods course for single subject teachers (mainly secondary teachers but also teachers of art, music, and dance that are certified to teach K-12) one of the beginning exercises for the secondary interdisciplinary teams' group work uses chromatography as an eye catcher. During this exercise, the students are given the following prompt: They are invited to observe and describe what they see during a paper chromatography investigation that uses a selection of water-soluble and water-resistant black markers with water as the solvent. For all the teams, the experiment is redone at least once in order to satisfy all the students. Afterward,

the chromatograms are passed throughout class, and students are provided with enough time and examples in order to be able to write to the prompt.

This case concentrates on a group of four students - Joy (a dance teacher), Martin (a science teacher), Sharon (an English teacher), and Darryl (a mathematics teacher). All four hold emergency teacher permits, and between them have an average classroom experience of about 1.5 years. Joy is the youngest of the four. She has needed to see the experiment twice, and afterward still questions how to describe what she has seen. Martin, Sharon and Darryl, though, are scribbling in their journals without taking their eyes of their papers. "Well, it is time to write," Joy says to herself.

She starts writing. "It started off as a black dot on a piece of paper partially submerged in water without having the black dot inside the liquid. As the water raises, a beautiful bird of paradise appeared before my eyes. Its head and wings emerged as the colors began to run. The body followed and its journey continued as the cup with the experiment left for the next row. As the second beaker was passed around the room, I tried to catch a glimpse of what I might have missed with the first experiment. By the time the beaker made its way to me, another bird emerged. His mate is not as bright and beautiful as the first, but its what's on the inside that counts."

Martin, the science teacher, is the first to finish writing. He is eager to share his writing with the group and reads aloud. His writing concentrates on the scientific explanations of chromatography, describing the differentiation between large/small molecules, solvents, paper/gel chromatography and the effects of pores and electric charges. Sharon, Darryl and Joy are impressed with what he has written. No one mentions that he has intertwined his observations with scientific explanation. Darryl, the mathematics teacher whose background is in engineering

and who has worked with organic solvents for a long time, contributes a few details when he reads aloud. Darryl adds, "Just think about drawing a plot of the length of the chromatogram and the place of each component after the run. It would be wonderful to see the relationship!" Sharon, the English teacher, decides not to share her writing but to correct the grammar of Martin's writings and rearranges his sentences. Joy does not know what to do. The instructor has asked each group member to share, and asked the group to negotiate and come up with one description for the group. After hearing her peers' "scientific" observations of the experiment in detail, she "knows" she has gotten it "all wrong." "Well, time to share!" she finally decides. After sharing her written observation with her group, the others decide that Joy's description is amazingly beautiful. Sharon states that she also saw the beautiful colors although she did not understand the scientific explanation. Martin and Darryl realize that somehow, in the process of learning and understanding science they have lost the capability to see "the bird of paradise."

When the group shared Joy's description with the class, science and mathematics teachers in other groups realized that there might be lots of students like Joy in their classrooms. By imposing one way to describe and interpret an experiment they, science teachers might destroy these students' creativity and diminish their success in science, a discipline that has so many avenues for creativity (such as model development, planning of experimental stages, interpreting results, etc).

Successful Interdisciplinary Collaboration Values Personal Culture

This story of interdisciplinary collaboration reveals a classic dilemma. Like in newly formed interdisciplinary team in the study by Collins, Bercaw, Palmeri, Alman and Singer-Gabella's (1999), the four EPTs had the same goal. In Collins et al.'s study of a newly formed interdisciplinary team collaborating to teach a university course in biology that emphasized good

pedagogy and the use of advanced technology, the goal was to enhance students' knowledge in all areas of the course's focus. In "It's a Bird of Paradise," the goal of the EPTs was to negotiate and provide a description of what they had observed. Like the professors teaching the university course, the EPTs also represented different cultures, cultures that prescribed different ways to achieve the common goal. In Collins et al. tension characterized the collaborative aspect of course development and the initial stages of teaching the course when personal cultures collided. Tension and discomfort can be inherent parts of newly formed collaborations when personal cultures collide and the individuals involved are unwilling to relinquish their ideas or compromise a position. In this situation involving the EPTs, tension did not develop into something unmanageable because the "non-science" individuals were willing to give up their description in favor of one that they perceived to be scientific and that they did not understand.

In "It's a Bird of Paradise," the dance teacher, Joy, was ready to forego her turn to contribute to the group's discourse as she was aware that the description in her notebook differed vastly from the "scientific" one presented by the science teacher. Joy felt more comfortable recognizing the "superiority" of Martin, a science teacher, than sharing her creation. Joy had previously shared that her self-esteem in science was very low; she had avoided science as a learner because she could never understand concepts that seemed "obvious" to others. The English teacher, Sharon, also had felt intimidated by Martin's description and explanation of chromatography. Sharon did not share her description with the group, though in actuality her description better reflected a description of the phenomenon observed than Martin's. She had written, "I saw one dot of black ink separating into different colors as the water was moving up the filter paper. Not all the black dots got separated." In the interdisciplinary secondary methods classroom this situation arose many times when an EPT did not understand the contribution of

his/her group members to the group's voice. On many occasions some EPTs even erased their responses and replaced it with the "group's" voice or answer.

After Joy had shared her description with her group, the group decided to employ Joy's description as the group's voice because of its originality. Sharing this description with the class was a total success, particularly since the other groups' presentations were more scientific in nature. Joy's response, with its tentative dancing movements describing the birth of the bird of paradise, caught everybody's attention. This decision to value Joy's written response demonstrated the EPTs' capacity to honor the diversity of their personal languages and cultures, which is a foundation of collaborative endeavors. This experience was essential for recognizing Joy as a team player in the interdisciplinary team. It increased her self-esteem and helped her to realize that in a group it is important for everyone to have a voice. She felt more confident to ask questions about the scientific aspect of chromatography and, to actually understand what is happening. For the science EPTs in the course, and Martin in particular, the experience was an eye opener. They realized that they needed to listen to what students like Joy had to say in their classroom if they wanted everybody to be able to learn science. Since the investigation with chromatography, Martin constantly asked for Joy's advice, as he wanted to increase the creativity in his seventh grade class assignments. He also chose to work with Joy on the final course assessment. Their interdisciplinary project was organized around "Diversity" as the theme. While Martin looked at the chemical elements, Joy decided to concentrate on the different dances in Hawaii. It was interesting to see these two individuals analyzing chemical elements and dance for their commonalties (e.g., protons, electrons, neutrons and certain movements that qualify for dance) and differences (e.g., numbers of the subatomic particles and rhythm). Martin and Joy's individual journeys culminated in the creation of an interdisciplinary team in which they

recognized their personal cultures and used their differences to improve the quality of their work in the course and teaching in their classrooms. In short, they honored their diversity of their areas of expertise, or their personal cultures, and developed a collaboration based on mutual respect.

In the next story four elementary school educators confront personal predicaments in their endeavor to design and teach a multiage interdisciplinary unit about Paleolithic cultures in Colorado. Like the EPT in "It's a Bird of Paradise," these educators had a common goal - to provide an opportunity for themselves and their sixth and first grade students to expand their understandings of the nature of science through use of inquiry-based pedagogy.

Story 2: What Have I Gotten Myself Into?

Four educators teaching in a rural K-12 school located in the Colorado mountains have been participating in Building and Reflecting About InterDisciplinary Studies [BRAIDS], an Eisenhower-funded grant providing professional devel̄opment for teachers in math and science in rural school districts in western Colorado. The BRAIDS project had begun with a one and one-half week summer institute. During this institute the educators had engaged in an intensive interdisciplinary inquiry in paleoarcheology at a newly discovered archeology site in the Colorado mountains. Guiding their initial inquiry were two essential questions: What is happening on this hillside? What's the hillside's history?

"What have I gotten myself into?" each, independently, wondered as the summer institute unfolded, and as they completed archeological, soils science, mapping, and field botany investigations to learn about who might have lived on the hillside, when, and how. Additionally they considered how they would use their new understandings in their classrooms.

To answer the pedagogical question, the four formed a team to tackle the challenge of planning and teaching an interdisciplinary unit focused on some aspect of paleoarcheology. This

unit would demonstrate their learning related to the BRAIDS project activities. The four educators were three classroom teachers with teaching experience ranging from one to twenty-eight years (Carol, Turtle and Jill) and one education student (Esme). Carol and Jill partnered together to design and teach a sixth grade component of the interdisciplinary archeology unit. Esme and Turtle partnered together for the first grade component. They decided that the culminating events at the end of each of the separate grade level components of the unit should involve peer teaching. The sixth graders would teach the first graders in a museum they would create. The first graders would teach the sixth graders. At this time the four educators would work together as one team. This was exciting yet daunting task. The task was exciting because it would give them a chance to put newly learned ideas to work. It was daunting because it involved so many unknowns. "How would each fit in? What would each contribute?," were their primary questions.

Carol is a middle school social studies teacher who has been teaching for 28 years. She had already designed and taught an archeology unit that she felt comfortable with. She was accustomed to using a deductive approach to teaching the unit that started with telling her sixth grade students that the environment determines the way a culture develops and culminated in a four day archeology field trip to an archeological site in southwestern Colorado. This unit was focused on the social studies curriculum with little or no thought of integration with other subject areas. It became the basis for her contribution. Carol decided that this opportunity could be a good one for "overcoming inertia," in other words, teaching the unit as she always had.

Jill is in her first year of teaching. She is starting a new program at the school as the Enrichment Coordinator, and is defining her position as the school year progresses. When she chose to partner with Carol to design and teach the sixth grade component of the unit, Jill knew

she was walking into an established situation. "The biggest challenge that I faced was feeling that I had something to contribute. I was excited to be partnered with Carol, who has years of teaching experience, and I was looking forward to learning a great deal by working with her. At the same time, I wondered what I could add to this archaeology unit that she had previously taught, and that we planned to use as the basis for our project." Jill, in her own right, is a competent teacher and easily assumes leadership roles. She wondered how the work with the BRAIDS project would mesh with her responsibilities as the Enrichment Coordinator.

Turtle is a first grade teacher with ten years of teaching experience, and she has a strong Montessori background. Her teaching philosophy is steeped in social constructivist ideas and is very child-centered. For her, "teaching in an integrated way is a natural way of doing things in her classroom.Young children best learn when fully immersed in exploration and when given long, uninterrupted blocks of time." Turtle is not happy with the structure of the school schedule, in which pull-out programs such as gym, music, special performances, and holidays break up the flow in her classroom. She constantly struggles with maintaining a flow while tied to the traditional school schedule. Turtle also has a strong desire to ensure that Esme, the education student who is doing a practicum in her classroom, gets to experience the teaching and learning related to the interdisciplinary unit. She wanted to be sure that Esme would be present when the investigations that formed the basis of the unit were occurring, so Esme could "see how messy real learning is and to have to be resourceful in meeting the emergent inquiries that arise unexpectedly. (These usually carry the most excitement, and can become some of the most productive and satisfying teacher/learner events.)"

Esme, who already holds an undergraduate degree, is an education student participating in a year-long practicum experience that includes student teaching. She has a well-articulated

teaching philosophy that meshes well with Turtle's philosophy. Esme is a very creative and compassionate teacher-to-be and constantly aims for excellence in all that she attempts. She is the only education student in the BRAIDS project, and on several occasions during the summer institute verbalized that she felt intimidated by the experience of the teacher participants in the project. "The greatest challenge that I faced with this project was overcoming my feelings of intimidation due to lack of experience. During the summer seminar, I was excited to be a part of this project, however, I did not feel like I had the experience or knowledge to contribute as much as the others." Turtle and Esme designed their interdisciplinary Paleolithic unit to be taught during a block of time in the afternoon on Mondays and Wednesdays, the days that Esme would be present. During these times scheduled activities interrupted the flow of their unit. The children would just get going and then have to stop. Turtle considered having the specials teachers do activities related to the unit, but the teachers were tied to their own agendas, such as holiday programs and preset curricula. The entire unit was going to have to be taught in her classroom.

Successful Collaboration Necessitates Changes in Thinking

Each of the four educators in "What Have I Gotten Myself Into?" were faced with predicaments related to their thinking about pedagogy or to themselves as teachers. To successfully teach the interdisciplinary cross-grade unit necessitated that they resolve these individual predicaments. How successful were they in these endeavors?

When Carol wrote her contribution to this story, she reflected on what has kept her teaching for 28 years. "Meeting new challenges and overcoming problems are undoubtedly the motivating factors. Integrating science and math into a social studies classroom would definitely be one of those challenges. An additional challenge is getting out of the comfort zone and enriching a previously established and successful unit and field trip on archaeology to include the

sciences. After all, I am not a math or science teacher at the moment, although I have taught both in my career. Having the time to meet my history, social studies, civics, economics, and geography standards is enough of a challenge in itself. How on earth can I add lessons in geology, mapping, mathematics, and botany to an already jam-packed curriculum, especially in a middle school program that is not really structured for integration? Where in the already strained class time can first graders become a part of the educational process of sixth graders?" She was open to enriching her own pedagogical knowledge, but doing so entailed dealing with the challenge of restructuring what felt comfortable to her - teaching in a way that was familiar and deductive in orientation. It also meant sorting through her issues related to curriculum pressures.

The first step in her journey entailed "overcoming inertia" - her tendency to repeat what she had done before because it is easier, especially if a program is working. Instead of using a deductive approach as the basis for the unit, she reframed the unit around essential questions that would guide her students' learning. "What is culture? What is in this environment that people of the past might have used to survive?" and "What are the environmental concerns that people in a culture might have had to contend with in order to develop a society?" became the starting points of student learning. Students engaged in a "nonscientific mock archeological dig site" and made inferences about the culture based on what they found. Students went outdoors to find things in the environment that would answer the questions. The opportunity for an integrated exploration of culture had commenced. Mapping to locate useful plants and other resources within an area, graphing a cultural pie in terms of the environment, or measuring accurately for a mock archaeological dig were stimulating science and math activities that set a stage for exploring ancient cultures. Carol was excited to re-discover how enriching an integrated approach to learning could be. The sixth grade component of the unit culminated in the sixth graders creating

a museum of cultures and taking the first graders through their museum. "Sharing the learning to teach first graders delighted the sixth graders and added one more level to the experience," Carol said. "Looking at new ways to organize the curriculum in order to get more bang, I believe, is the beauty of an integrated design." She "was still having trouble with the science part" but she was looking at new ways to organize the curriculum. According to Jill, "Carol did a great job at integrating the components and getting the kids to really think, inquire and ask [the questions such as] Is this an observation? Or is it an inference?"

In Jill's case, as the teaching of the unit got underway, she discovered her niche, that of a "support person." "I was a second teacher in the room when the class split in two for certain activities. I was another adult-chaperone-teacher on the four-day archaeology field trip to the Four Corners. I helped students with their reports and Living Museum exhibits, arranged for newspaper coverage of the event. In general I provided whatever assistance I could to Carol." Although she was not in a leadership role in the teaching of the unit, she eventually came to view her role as essential to the success of the unit. "It took time for me to find my place and become comfortable with my role. I had to change my expectations and way of thinking to get to this point." Jill's acceptance of her role as the other teacher in Carol's classroom provided her with an opportunity to see and to be able to ask for explanations from an experienced teacher. Through this action she was also demonstrating her sensitivity toward an experienced teacher's perceptions of control and roles in the classroom. In the end, Jill realized that she offered a valuable contribution to the success of the unit.

Turtle resolved her frustrations about scheduling and not being able to "orchestrate the children's aha! moments" so that Esmé could experience them by developing a different approach to dealing with time. Instead of the first grade curriculum being a set sequence of

activities performed by the whole class, she developed a list of tasks to be accomplished by each child at his/her pace. The Paleoindians unit activities were on this list. When interruptions due to pullout programs or specials classes (art, music, physical education) took place, they would minimally disturb the children. After there was an interruption the child would return to the task and pick up where he/she had left off. In the meanwhile, materials were left undisturbed during the interruptions or on trays that could be set aside. New ideas would be introduced to the children on days when Esme was present, thus allowing for Esme to witness children's aha! moments as they arose.

Turtle and Esme had used a centers-based, guided inquiry approach for learning in the unit. During the design process Esme revealed her creativity to her future mentor. Though Turtle thought well of Esme's abilities and talents, Esme still wrestled with issues of confidence until she actually began teaching the unit in Turtle's classroom.

The first grade component of the unit began with the children's brainstorming regarding "Who lived here first? What do archeologists do? Their visit to the sixth grade museum followed. Once Esme and Turtle began teaching the unit, though, Esme "began to feel more comfortable, was able to follow Turtle's lead and eventually teach small lessons on my own." They did a mock dig using trash from Turtle's home. They went outdoors and collected materials from the local environment to serve as data for investigating how people over time might use the materials. On a daily basis the children wrote reports about their data and inferences in journals. Esme worked with students in small groups or on a one-on-one basis in the centers that she had helped to design. This grouping structure allowed her to refine the centers-based activities into mini-lessons and to individualize her instruction. It provided Esme with opportunities to witness the children's struggles and aha! moments, and to realize that, though inexperienced, she had

something to offer a team of more experienced teachers. The outcome of her journey was increased self-esteem: "Through this experience, I was able to overcome my lack of confidence and to feel more comfortable working with experienced teachers." The tension described by Collins et al (1999) did not develop because the participants knew how to negotiate roles in order to maximize the success of this experience.

Each of the educators in the team undertook different journeys that led them to a shared destination, what Minstrell (2000) labeled as "intellectual pleasure." For these educators, the destination centered on feelings of personal success about their collaboration and the pleasure of an interdisciplinary, inquiry-based, cross-grade unit that their first and sixth graders enjoyed. In this study we looked at collaboration as the factor influencing teacher change. Jill's attempts to understand Carol's actions in class helped Carol to confront her own teaching "inertia" by shifting her thinking about appropriate pedagogy. Jill created a niche for herself in an established teaching situation by changing her expectations to realistically meet the task at hand and by becoming the learner and support person in Carol's classroom. Turtle's interest in sharing her students' "aha!' moments with Esme contributed to Turtle's overcoming the difficulties of a chopped up daily schedule and the need for a synchronized curriculum by providing her first graders with an opportunity for individualized learning and guided inquiry. Esme found that jumping in and actually teaching with Turtle as a guiding teacher gave her the confidence she was lacking when she was working with experienced teachers.

In the situations described in this study, collaboration and the roles of participants in collaborative situations appeared to be the main influence determining dynamics and providing solutions to dilemmas. Linn and Burbules (1993) identified three different situations involving individuals learning in groups: tutoring, cooperation, and collaboration with the collaboration

situation requiring the most advanced social skills" (p. 112). Tutoring describes a situation where one participant having more expertise or status teaches another or other participants. Cooperation is described as the situation where participants divide the task at hand, handle separately the different parts, and combine the parts to form a whole. During collaboration, which requires the most developed social skills, participants share and negotiate ideas all along the duration of the project for the good of the group by taking into consideration all the voices and perspectives.

Applying these principles to our study, there were numerous situations of tutoring in the two stories: Martin tutoring Joy in the chemistry of elements, Joy tutoring Martin in elements of dance, Carol tutoring Jill in elements of pedagogy, Jill tutoring Carol in elements of inquiry. Instances of cooperation include when each one of the teachers correlated developed curriculum to content standards. Collaboration surfaced when the EPTs negotiated their group description of an observed phenomenon, when the EPTs decided on the general theme of their interdisciplinary unit, and the Colorado educators negotiated the approach and structure for their grade level unit components as well as the cross-grade culminating activities. It is important to note that because these eight educators were able to recognize each other's areas of expertise, there was no resistance to receiving information during tutoring situations. Participants were eager to understand the other's point of view and to use their points of view as an enrichment element.

Implications for Science Education

The eight educators involved in the interdisciplinary learning opportunities related in the two stories began their journeys with personal inquiry into some aspect of scientific inquiry (respectively, chromatography and paleoarcheology). The journeys culminated in "intellectual pleasure" (Minstrell, 2000) in terms of their personal accomplishments and a richer awareness of what it means to honor a diversity of cultures of science and pedagogy. During their journeys

each, individually, wrestled with what they considered to be science and best pedagogy for their students, and what was needed to work collaboratively in a group. As these educators confronted the dilemmas that emerged during their journeys, they constructed a richer understanding of how educators can collaborate to provide meaningful science learning experiences for themselves and for the students in their classrooms. The EPTs clearly constructed a richer understanding of what science can be whereas the Colorado educators' focus was on issues of general pedagogy and on reflective pedagogy that supports inquiry endeavors. These orientations are not unsurprising, given the priorities of their educational situations. The EPT engaged in multiple guided inquiry investigations in their interdisciplinary secondary methods course. The repeated examination of the nature of scientific inquiry as a means to develop pedagogical content knowing (Cochran, DeRuiter, & King, 1993) was a pulse in the course. Furthermore the course professor closely mentored their inquiries. The Colorado educators had engaged in a several day, guided inquiry investigation at the beginning of the professional development project. They were then to use the understandings they had constructed to design an interdisciplinary unit based on archeological inquiry. Throughout the project they presented reports of their progress. Thinking about inquiry-based pedagogy, the nature of learners, connections between the disciplines, and curriculum design in a collaborative manner) - aspects of their personal practical knowledge (Connelly & Clandinin, 1988) -dominated these educators' learning.

In many instances of the use of interdisciplinary approaches to science learning involves collaboration between educators who have different personal cultures of pedagogy and science. Akerson and Flanigan's (2000) study highlights a problematic in collaboration - teacher unwillingness and absence of openness to collaborate. In this study topics learned in a language arts methods course were to be integrated into a science methods course for elementary teachers.

The science methods course instructor, however, was not receptive to collaboration. Hence no common planning between the instructors of the two courses ensued and any integration that occurred was the result of two factors. First, methods students holding a strong personal interest in making connections between their learning in the two courses applied what they had learned from one course to another. Secondly, the instructor of the language arts course helped the methods students develop a thematic unit in science that was also taught in an elementary classroom. The teaching of the unit provided an opportunity for the methods students to experience the potential of an interdisciplinary approach to learning. Collins et al. (1999) also reported on an unsuccessful aspect of collaboration when a group of professionals did not have the necessary time and experiences in order to negotiate a common culture based on respect and honoring diversity. Their group did not reach the "intellectual pleasure" (Minstrell, 2000) involved in successful collaborations.

These studies point out the significance of teacher willingness and openness for collaboration. A teacher needs to have the courage to initiate, to be willing to listen, and to negotiate. As group members, they need to be willing to be supportive and respectful in the face of differences. In the two stories presented, the eight educators exhibited these qualities, and thus their collaborative efforts were successful on many levels. These educators were able to honor the diversity within their learning communities.

Successful collaborative endeavors were reported in Akins and Akerson (2000) and Saam (2000). In the former study three teachers and a student teacher used an interdisciplinary approach to teach a fourth grade class of 26 students. The three teachers rotated according to their area of expertise while the student teacher always remained with the class. Through numerous discussions the four individuals responsible for teaching this fourth grade class

coordinated their curricula so they could take advantage of the concepts to be taught by the team. The resultant cross-disciplinary curriculum contributed to the children's increased understanding of the interrelationships between the various school disciplines and the teachers' capabilities to increase children's success in one area through using another; for example, increasing knowledge in science using language arts. In the latter study a team of science and mathematics teachers fully correlated their curricula to result in the use of concepts taught in mathematics to solve problems in science, and vice-versa, rather than to use an approach in which each concept in the different disciplines was re-taught in the separate classes. By the teachers modeling collaboration and the students experiencing a fully correlated curriculum, the students came to understand the meaning of collaboration.

These two studies point out the need for continuously searching for and making explicit appropriate connections across knowledge bases, and then using these connections as a focus for student learning. Secondly, these two studies allude to the nature of successful communication for collaboration, communication in which each individual listens to the ideas of others, steps beyond personal agendas and vested interests, and places a shared learning goal at the forefront of the planning and teaching. In the first story presented in this paper, the EPTs moved beyond personal agendas into a collaborative situation that required a shared learning goal in an atmosphere that honored the different perspectives through recognition of expertise areas. In the second story, the four educators also moved beyond personal issues to benefit their learning goal that, for some, included changing their philosophies of teaching and increasing student ownership of the learning process and learning through inquiry.

Not explicit in the stories as presented, but in the discourse leading to the generation of the stories, was a perspective that, although challenging and not necessarily easy, using an

interdisciplinary approach for curriculum development and teaching can be a powerful means to create and sustain standards-based schooling. All eight teachers discovered that the interdisciplinary teaching units addressed a multitude of content standards from each discipline. In short, the accountability factor that their teaching must be aligned to standards was almost an aside for the teachers. A standards-aligned curriculum was a necessary side-benefit that satisfied political forces related to the language literacy emphasis in contemporary schooling and with addressing content standards at all levels.

We strongly recommend the use of these interdisciplinary "conspirational texts" (Barone, 1990) in professional discussions and the analysis of their effect on the development of the higher- order conceptual skills (Zoller, 2000) of our teachers, as well as their effect on the student population. Such interdisciplinary endeavors also have the potential to elucidate some of the mysteries that still exist at the level of the necessary skills for successful collaborative efforts and their effect on cognitive knowledge construction (Linn & Burbules, 1993).

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THE GENESIS OF SCIENCE TEACHING IN THE ELEMENTARY SCHOOL: THE INFLUENCE OF STUDENT TEACHING

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Theoretical Background

Bandura (1977, 1986, 1995, 1997), Fullan (1993), and other self-efficacy researchers have concluded that the genesis of deep change in the educational system is the individual teacher and that a teacher's behaviors, values, beliefs, and ambition to act may be cultivated or inhibited during his / her early experiences as a student teacher. Therefore, this paper examined the experiences of student teachers, utilizing the theoretical framework of self-efficacy, to determine if their science teaching self-efficacy beliefs changed during this crucial early stage of their prospective teaching careers. It was also reported as to the factors or events that produced the changes.

The examination of self-efficacy and outcome expectancy in relation to teaching has been the foci of studies by several researchers (Ashton & Webb, 1986; Enochs & Riggs, 1990; Gibson & Dembo, 1984; Guskey, 1988; Woolfolk & Hoy, 1990). Personal teaching efficacy has been defined as a belief in one's ability to teach effectively and teaching outcome expectancy as the belief that effective teaching will have a positive effect on student learning. Research on efficacy of teachers suggests that behaviors such as persistence at a task, risk taking, and use of innovations are related to degrees of efficacy (Ashton & Webb, 1986). Highly efficacious teachers have been found to be more likely to use inquiry and student-centered teaching strategies, while teachers with a low sense of efficacy are more likely to use teacher-directed strategies, such as didactic lectures and reading from the textbook (Czerniak, 1990).

Relation of this Work to Other Efforts / Statement of the Problem

The literature abounds with research depicting elementary science teacher education as

lacking in areas that will equip and entice preservice teachers to effectively and consistently teach science to elementary students once they enter the inservice teaching realm. Many studies have focused upon the link, or lack thereof, between preservice and inservice elementary teachers' implementation of the teaching of elementary science (Ginns & Watters, 1998b; Crowther, 1998; Ginns & Watters, 1990). However, the research literature does not have ample documentation as to the student teaching factor. Granted, first and second year inservice teachers, with all of the pressures and nuances of school life, will not exhibit the influences of the university science methods class, even if that class was instrumental for the preservice teacher at the time it was taken (Ginns & Watters, 1998b; Weiss, 1997; Tilgner, 1990). A longitudinal study of the preservice to inservice transition would be interesting, but it would only prove what is already known: that no matter what is taught at the college of education level, inservice elementary teachers are not teaching science to their children effectively (Ginns & Watters, 1998b; Weiss, 1997; Tilgner, 1990). More specifically, some teachers teach science to elementary students more often and effectively than others. The reality of the problem is to explore the barriers for the teachers who are not teaching science effectively. It is known statistically that this is a major problem with science education, but it has not been systematically analyzed as to why this is.

This study was unique in garnering an early view at how the deterioration of science education begins. It allowed for an opportunity to view the genesis of the process of energetic and enthusiastic student teachers metamorphosing into the ineffective inservice science teachers who are thoroughly highlighted in the research literature.

The explicit research question shaping this investigation was: What is the impact of the student teaching semester on preservice elementary teachers' personal efficacy beliefs and outcome expectancy beliefs in science teaching? Specifically, the objectives of the study were to:

a. analyze student teachers' experiences in the elementary science classroom and in the school for factors that impacted on their beliefs about their ability to teach science; and

b. identify factors that contributed to the effective teaching of science by student teachers.

Methods

A series of individual interviews and observations, before, during, and after the student teaching "soloing period" was conducted with the chosen informants to gather qualitative data. These semi-structured interviews were used to investigate the informants' recall of experiences that might be interpreted as affecting their beliefs about science and about their ability to teach this subject.

Subjects

Three cohorts of preservice elementary teachers (n=59) were the subjects of this study. Each cohort began its student teaching semester (fourth and final semester) at a large four-year university in the western part of the United States. Through a series of qualifying and sampling techniques, six informants were chosen for in-depth study.

Results / Conclusions

The student teachers' beliefs in their abilities to teach science effectively, having a positive impact on their students, significantly declined from the beginning to the end of the student teaching semester. After analyzing the responses from the interviewed student teachers, the factors which impacted upon their beliefs became clear.

Three specific areas of their preservice elementary school experiences unfavorably molded their beliefs in their science teaching effectiveness:

- mentor teacher influence;
- curricular time for science; and
- materials and equipment needed to implement hands-on science activities.

Relevance of this Work to Science Teacher Education

This study demonstrated that preservice teachers' beliefs and attitudes about science

teaching are set firmly prior to entry into preservice programs as a result of their science related experiences in elementary and secondary schools. The study also found that these beliefs and attitudes are further amplified through the science content courses digested at the college / university level. Logically, preservice programs ought to provide situations which produce positive changes in preservice teachers' beliefs about their ability to teach science. These programs should also make them aware of the causes and nature of concerns that they might be exposed to in their student teaching semester (such as lack of materials, not enough time to teach science, extra-curricular activities, and mentor / tenured teachers' biases towards the teaching of science).

Implications For Elementary Preservice Science Teacher Preparation

This study has several implications for elementary preservice science teacher preparation. Based upon the findings of this study, the following can be recommended:

1. Recruit mentor teachers who readily teach effective science lessons. This would ensure that preservice teachers receive affirmation that they were implementing successful science lessons, or minimally, that they would observe positive role models as their mentors teach science in the elementary classroom.

2. Provide funds for science materials and equipment needed to implement hands-on science lessons during student teaching. Easy access to these supplies and equipment would enhance the student teachers' roles as science teachers in the classroom. A related possibility is to seek external grant funds to develop and support a system for student teachers to borrow and use equipment.

3. Stress the importance of integration within the curriculum. This is important due to the fact that elementary school teachers are inundated with curricular and extra-curricular demands. By teaching an integrated curriculum, teachers would be able to include all curricular areas without restricting the involvement of any one subject area. Since modeling is such a

powerful teaching technique, integrating instruction should be utilized by all preservice methods instructors. Further, methods courses in the preservice programs should be integrated together by the specific methods instructors. Additionally, mentor teachers who are integrating curriculum effectively should be utilized as effective models for the preservice teachers.

4. Determine the preservice teachers with high self-efficacy in the area of science education using various measures such as utilized in this study. These individuals should be identified and embraced as peer role models and tutors for the preservice teachers who are lacking in self-efficacy in the area of science education. They could also be acceptable role models for inservice teachers who need assistance in the science arena.

5. Conversely, identify preservice teachers with low self-efficacy early in the program and provide them with assistance from both the preservice teacher coordinators and the mentor teachers. Take steps to bolster their science teaching self-efficacy, which will in turn help improve their science teaching effectiveness.

Moderating and ameliorating the concerns of preservice teachers may assist them in experiencing initial success in teaching science and enhance their own personal beliefs about their ability to teach science. This would, in turn, ensure their professional growth and commitment for teaching science in the elementary school.

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GOALS 2000 AND ACTION RESEARCH: A VIABLE PLAN FOR TEACHERS

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Action research is a form of research that has received a great deal of recent attention. Many traditional researchers maintain that action research is a lesser form of research, while many practitioners advocate and use forms of action research on a daily basis to increase understanding and make changes in classroom or educational settings. Action research is now receiving more attention at the higher education level (outside of the social sciences where action research has its origins) with several texts written on specific methodology in education (Spiegel, Collins & Lappert, 1995; Schmuck, 1997; Mills, 2000). In a recent editorial of *School Science and Mathematics*, Lederman and Niess (1997) wrote of the increasing advocacy and critical component that action research provides to both the practitioner and the math and science education research base. We even see examples of action research (or at lest some results of action research) seeping into science education journals such as *Journal of Science Teacher Education*, *Journal of Research in Science Teaching*, *Electronic Journal of Science Education*, *School Science and Mathematics*. Other science education journals actually advocate and print action research including *Science and Children* and *CESI Science.*

The purpose of this research is simply to explore action research as a tool for teachers in a professional development program using action research methodology to establish the quality of research, the usefulness of research, and the publishability of action research in the science education community. The project was composed of the Lane Education Service District (Eugene, OR) Goals 2000 project which provided instruction on action research methodology to

over 208 participants, support and stipends for teachers to carry out and write up their projects, follow-up instruction and survey data on participants.

Background

Project Goal

The goal of the 1999 Lane County Consortium Goals 2000 Science Project is to improve student achievement in science at all benchmark levels through teacher research.

Grant Participants

The project includes eight Lane County school districts, 27 schools and 208 teachers in grades K-12. In order to receive Goals 2000 funding, schools must maintain a minimum participation level of 80% of all teachers in a benchmark cluster.

Higher Education Partnership

The grant Higher Education Partner is the Academy for Excellence in Science and Mathematics Education at Oregon State University (OSU).

Summer Science Institute

Teachers registered for a Tuesday -Wednesday or Thursday-Friday series of workshops at a Summer Institute held August 24 - 27. The workshops were offered at benchmark levels K-3, 4-5, 6-8 and 9-12. Workshops addressed specific content strands, instructional strategies, scientific inquiry, science assessment, and action research. Workshop sessions ran from 9:00 a.m. to 12:00 noon, and from 1:00 p.m. to 4 :00 p.m. both days and teachers received a stipend of $250.00 to attend four workshop sessions. Graduate credit from Oregon State University was available for nominal cost to participants.

Classroom Embedded Action Research

The goal of the action research was to provide teachers with the opportunity to explore, in their classrooms, creative approaches to meeting the standards, to create inquiry lessons scored

with the science scoring guide, and to improve their science teaching. Teachers selected a research topic or question related to improving student achievement in science. The research topic was to be of interest to an individual teacher or may have been a collaborative topic within a school or group of teachers. Topics ideally fit in with everyday teaching and were to be manageable in terms of time and scope. Teachers then collected data, evaluated the data, and reported on the data. The time frame for the action research was September 1999 through April 2000. Teachers were expected to spend a minimum of 16 hours (outside classroom time) in addition to classroom time on action research. In addition, one day of substitute release time was provided for teachers to work on action research projects - for reflection, planning, collaboration, peer coaching or classroom/school observations.

April 2000 Symposium

A symposium open to all grant participants was held in April 2000 to share the results of the action research projects. At least one team from every school was asked to participate and to share the results of all participants' action research. The goal of the symposium was to celebrate successful teaching strategies and share good lessons and practices. All participants were required to submit a summary of their action research findings for publication in a summary document.

Principals Involvement

All participating principals were to attend a workshop on facilitating action research and were to be instrumental in coordinating action research projects at the building level. Principals were encouraged to discuss the progress of action research throughout the year and to attend the Symposium in April 2000. Additional support for action research projects was available throughout the year from the higher education partner and the project director.

Methods

For this study a mixed methods survey design was utilized. "Survey research," according to Borg, Gall, and Gall (1993), "typically employs questionnaires and interviews to determine the opinions, attitudes, preferences, and perceptions of persons of interest to the researcher" (p. 219). These authors further discuss that survey research is an effective way to explore a number of issues in education and it lends itself well to program evaluation. Creswell (1994) discussed survey research as a design which provides both quantitative and qualitative descriptions of some portion of the population through the data collection process of asking questions of people. He further explains, "This data collection, in turn, enables a researcher to generalize the findings from a sample of responses to a population" (p.117).

The 1999 Lane county Goals 2000 workshop had 208 teachers involved in the study. A response rate of 50.4% was achieved on the qualitative survey. This survey initially had a lower response rate, but after a mailing many more responses were collected. Dillman (1978) noted that response rates vary due to the type of survey administered and that typically, in mail surveys, response rates are much lower. Reasonable response rates, in general, run from 65 - 80% in most situations. However, he stated that "it is not surprising, then, that users of the mail questionnaire treated response rates well below 50 percent as 'acceptable'" (p.3). The response rate for this study was deemed to be in the "acceptable" range.

Participants

The project includes eight Lane County school districts, 27 schools and 208 teachers in grades K-12 (Eugene, OR.). In order to receive Goals 2000 funding, schools must maintain a minimum participation level of 80% of all teachers in a benchmark cluster.

Instrument

The instrument used in this study was a pilot survey constructed by the authors to gain demographic information and to provide program evaluation information. The quantitative portion of the survey asked demographic information regarding the participants school district, school, number of students in classes, and teaching history / experience. Qualitative questions dealt with program evaluation dealing with the action research component of the professional development project. (See Appendix A).

Data Collection

The survey was administered in two parts. The demographic information was collected at the beginning and end of the project. The qualitative survey questions with program evaluation for the action research project was administered at the April, 2000 symposium when the participants shared their projects with one another.

Data Analysis

The demographic results were collected and tabulated using primarily frequency analysis. Where applicable, basic descriptive statistics were used resulting in data means for the population. Although data analysis in most qualitative research coincides with the data collection, the procedure of both is more like a process. Anderson (1993) explained that once data is collected the researcher should "(o)rganize the data into descriptive themes. The particular themes will emerge from a content analysis of the data..." (p.162). Bogdan and Biklen (1992) concurred with Anderson in that "As you read through your data, certain words, phrases, patterns of behavior, subjects' ways of thinking, and events repeat and stand out" (p.166). The qualitative questions from the survey were analyzed using the above suggestions. Each of the qualitative questions from the survey were categorized into themes and sample statements are included in the results section.

Results

There are two data sets where results were collected. The first is the survey that was administered at the follow-up workshop and the second was anecdotal data collected from final reports, research journals and informal interviews with participants and involved personnel. For this project, only the survey results will be discussed as the anecdotal results mirror the comments made in the final survey.

Survey Results

The Goals 2000 project utilizing action research imbedding in classroom instruction impacted 8 districts comprising 27 schools and 208 participants. The results of the survey maintained that the Goals 2000 project impacted roughly 6,000 students. The survey had a response rate of 50.4% and included many accolades for the entire program. The researchers were interested in specific responses to six open-ended questions:

1. Briefly describe your action research project and list the major steps that you took in order to carry out the project.
2. Do you feel by doing this research in your classroom, it has had an impact on your science teaching? What changes will you make based upon this knowledge?
3. Do you think that action research is an effective way to take a critical look at the way science is taught and learned in your classroom?
4. Do you feel more confident about your science teaching capabilities after conducting this research?
5. Do you think that the training and materials provided in teaching you how to do action research was adequate for you to carry out his project?
6. Are you considering or would you consider doing action research on your own, in your classroom, at some future time to learn more about your teaching?

The first question asked the participants to briefly describe their research projects and list the steps involved in doing action research. The purpose of this question was to discern whether or not the teachers learned and applied the 5 basic steps of doing action research, as they were taught in the teacher training seminar.

The action research projects undertaken for the Goals 2000 professional development program fit into 4 major categories . The first category of research dealt with projects where teachers provided instruction using observation skills to improve comprehension of science content. The second dealt with projects dealing directly with using the Oregon State Benchmarks, including assessments, objectives and scoring guide, to design lessons for the purpose of improving their science instruction. The third included projects that utilized teaching science content through science inquiry strategies and then measured student performance in a variety of different ways. The fourth category involved teaching content science using a variety of graphic organizers included in their science instruction (e.g., concept mapping). All research questions had a common hypothesis that students would do better in science by learning content through one of these strategies.

The workshop taught teachers a 5 step process on how to approach action research. A slight majority of 56% did not list any specific steps to doing action research, although they conveyed a narrative format of what they did. These respondents did not follow the steps as they were outlined in the training seminar, but still had a semblance to a "research" approach or design. Thirteen percent reported 3 major steps to doing action research including come up with a question, carry out research and evaluate. More than a quarter (27%) reported all five steps as originally taught in the workshop and handout materials for the project.

Question two asked the teachers if the action research project had an impact on their science teaching. The question also asked if there was an impact, what changes took place due in their teaching as a direct result of being involved in the project.

One fifth (20%) of the respondents did not answer the question and (15%) felt that it really had no impact on their current practice. Although representing over a third of the responses from the survey, no respondents explicitly stated that there was no or negative impact on current practice. The other 65% felt that the project had made a difference in their teaching and consequently on student learning in their classrooms. Example quotes included:

"Science for my class became exciting. Hands-on inquiry was a focus and it transferred to student learning in the classroom."

"Yes - Our team moved from a general discomfort with teaching science to being Jazzed with science and science inquiry."

"I taught observation skills in science. Surprisingly, the students carried that over to other subjects throughout the year."

"Yes, throughout the year I continued to make more connections to the nature of science tenants and then conveyed those on to my students."

For question three, teachers were asked if action research was an effective way to take a critical look at the way science is taught and learned in their classroom, participants answered in a variety of ways. Only three respondents stated that action research was not an effective way to look at their teaching. One response just had the word "no"where as the other two responses made the statement that teachers are asked to do too much already. "The drawback is that action research is being conducted in a setting where teachers are asked to do more, more, more - there must be a better way." The other stated that it was "too much extra work in an already too busy profession."

The negative responses are far outweighed by 93% of participants who felt that action research was an effective way to look at their own teaching and learning of science in their classrooms. Of these 93%, three respondents wrote the word "yes" and one wrote the word "absolutely." The other responses were categorized into themes: Self Reflection, Teaching Methods, and Student Benefit.

The theme with the greatest responses (50%) dealt with teachers who felt that self-reflection was the most valuable thing that they gained from doing action research. Sample responses included:

"By being actively involved I was more aware of what I was doing all the time and in other subjects besides science"

"The biggest benefit of action research is that it gives me an organized way to look at and reflect upon my teaching."

"Yes, because teachers stop and think about what they are doing in a more systematic and reflective way."

The second most popular response (29%) included comments about understanding and improving science teaching methods. Sample responses included:

"Action research became a valuable tool in looking at the curriculum and how it was being taught."

"It makes you stop and think about the types of activities you do in your classroom and you question if the activities that you are using are really inquiry types of investigations."

"This training has given me the tools to teach science better."

The smallest response (14%) stated that students benefited from their participation in doing action research. Sample responses were:

"Students became engaged in the experiments, stretching their thoughts and questions, and resulted in them wanting to share what they tried and learned."

"Yes, I would see the students figure it out? If not, they would keep working to discover as much as they could."

"Yes, I gained more confidence in my students abilities to do investigations."

Question four asked respondents if they felt more confident in their science teaching capabilities after conducting the research.

Close to one-fifth (19%) of the respondents did not answer the question and 3 respondents felt that the program really had no impact on their confidence. Of the three respondents, one thought that he/she "was already an exceptional teacher," another stated that he/she "felt the need for further collaboration within a K-12 framework before they could be more confident," and the third stated that he/she was "a second year teacher, confidence is still not part of my vocabulary!" Although representing about a third of the responses from the survey, no respondents explicitly stated that there was a negative impact on their confidence in teaching science. The remaining 69% answered the question in the positive realm. Forty-six percent of those respondents said "yes" that they were more confident in their science teaching and provided comments supporting that fact. Sample responses were:

"Yes, more confident because there is less worry about being the expert."

"Yes, every time I take time to think about, do, and examine any area of my teaching and student learning I get better and feel more confident."

"Yes, more confident than before the research started, the students became more excited about science, which helped me to create and look for more ways to teach inquiry science."

The remaining 23% responded that the project allowed them to gain knowledge, more resources and were more aware of doing inquiry science which may contribute to their overall confidence in teaching science as a result of being in this program. Sample responses were:

"I am not sure "confidence" is the right word. I feel like I have better insights into students learning and that often makes me feel better and more inspired to keep working at it.

"I felt pretty confident before, but this helps me to improve and fine tune."

"I appreciate the fact that I have gained more knowledge, more resources, and great teaching ideas - so it is getting better - I will do things differently."

The fifth question dealt with the quality of the packet and the training provided in the workshop. The results of this question were split. Fifty-nine percent responded favorably, although many of those responses included improvements for next year, whereas 41% responded negatively and listed specific concerns about the training.

The positive comments ranged from the word "yes" (11%) to some detailed positive comments about the workshop including improvements to be made. Sample responses were:

"Yes - it was a foundation of a new way of doing science - good stuff!"

" Yes, the summer workshop was fun, educational, and helped us to begin to pull together this project."

"Yes - they were adequate training and materials, however, more specific hands-on activities that goes step by step through the inquiry process that models activities that go on and on - including extensions"

"Yes, it was adequate, but I don't feel that action research is real research."

Of the 41% negative comments, the participants freely voiced their opinions. Only 2 respondents indicated "no." Several participants voiced an opinion about the journals being too time consuming and could have spent their time on other things related to the project. Others

expressed a desire to meet more often with other participants. An overwhelming majority of the negative responses (27%) indicated that while the packet was adequate, the training provided was insufficient. Sample responses were:

"It was somewhat confusing. We weren't sure what all the steps were that we were responsible for."

"Some of us received different information than others. We had some initial confusion over requirements, however, what we did receive was helpful."

"I felt that it was way too extensive. I felt really unclear about what was expected for this project and in the end I felt like I did things I didn't need to do because they were requirements at the beginning - then I was told that they were not needed.

"No - research design and construction needed to be better addressed."

"An additional in-building visit from a project person would have been helpful to clear up questions."

Question six asked the participants if they would consider doing action research on their own, in their classroom, at some future time to learn more about their teaching? Only 9% of the participants said that they would not do action research in their classroom. Of those 9%, two respondents just wrote the word "no." Other comments included "not at this time" and comments dealing with "time as a factor for not doing action research. Twenty-one percent of the respondents said that they might (or maybe) would do action research in the future. Most of these respondents simply said "maybe," "maybe / yes, " or "possibly" without any other comments. Those who made comments suggested simplifying the project or having it more informal.

The real success of any program lies within how many people would consider continuing things learned. The overwhelming majority (70 %) said "yes" they would do action research at a

future time in their classroom. Of these 70%, 38% responded with either "yes"or "sure." The other 32% (of the 70%) also said yes, but included some narration. Many respondents felt that they have done and currently do types or forms of action research in their classrooms. Others said that this type of research has formed collaborations with colleagues that will continue and spoke of new opportunities of things to study. Sample responses were:

"Yes, definitely, I feel like I do action research all the time. Trying something, reflecting on students' understanding, and moving forward..."

"I will do this in the future, but I believe I have been doing something very similar to this for the past 10 years as new standards based programs are introduced by the state."

"Action research is a fantastic learning tool. There really are a lot of opportunities to conduct inquiries."

"Yes, we (our team) are planning to continue this research while converting existing teacher-directed labs to inquiry based labs."

Conclusions and Discussion

Overall, the 1999 Lane County Goals 2000 Professional Development Project appears to be successful. Teachers were taught how to do action research in their classrooms, collected and analyzed data, and reported the results to their peers. The majority of teachers responded favorably to the project and felt that they had learned and gained from their involvement with this project. A full two-thirds to three-fourths of the respondents felt that action research is an important tool for classroom teachers. The majority of teachers said that the tool improved classroom instruction and helped them understand how to do research that was relevant to their individual classrooms and instruction.

Although the program should be considered a success, improvements can be made. The participants felt that clearer guidelines and more instruction on specific action research

methodology would prove helpful and necessary. Instruction should be made more consistent and more contact with other peers during the research time as well as program coordinators would be very helpful for more success in the classroom. Several participants developed a relationship with personnel at OSU as a result of this project and felt that the relationship was very helpful in finishing the project. More participants could benefit from this type of an experience.

Recently, the U.S. Department of Education (2000) released a three-year longitudinal study on professional development. It found basically no change in practice from teachers in the study. However, there were variances between teachers. When these variances were examined, they found that some professional development programs were more effective than others. The study identified "six key features of professional development that do improve teaching practice: Three structural features (characteristics of the structure of the activity) - reform type, duration, and collective participation - and three core features (characteristics of the substance of the activity) - active learning, coherence, and content focus" (p. 59).

When the 1999 Lane County Goals 2000 Professional Development Project is compared with constructs that are outlined in the U.S. Department of Education's findings, the workshop contained all six features that produce improvement in teacher practice. In addition, the project also had teachers reflecting upon practice, which although not included as one of the key program components, has been shown to improve teacher practice in a number of professional development programs.

Ultimately, the professional development program is not what makes the change in a teacher's practice; it is only the vehicle that provides an opportunity for change. Teacher must be able to explore their own practice and want to improve upon it. In doing so, changes take place. Action research in a content area (science and math) where the participants are active

learners in the research, and in a coherent program over a prolonged duration of study (1 year) that is based in reform efforts and provides a collaborative setting for teachers, is a ripe arena for teacher change. Although there is no empirical evidence that the 1999 Lane County Goals 2000 project produced change in Lane County classrooms, there is abundant qualitative data which states that it did have both a positive and lasting effect on the majority of participants and their classrooms.

Is action research a true form of research? Authors still argue this point regularly. Is action research a good form of professional development? In the case of this project one must conclude that yes it was effective, but still could be greatly improved upon. Can the action research projects from this study be publishable? Most likely not. One of the weaknesses of this project was in the instruction of how to set up and carry out action research projects with better controls. For action research to be more publishable in science education periodicals, more specific training in action research methodologies must be undertaken as this study found. However, more and more action research projects that are done with the proper methodology by classroom teachers are showing up in the literature.

A more controlled study of professional development utilizing action research for teacher change in classroom instruction needs to be done. Empirical data needs to be collected to assess both the change in teacher performance and student improvement and learning.

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THREE NON-WESTERN EUROPEAN STUDENT TEACHERS' CONCEPTIONS OF TEACHING SCIENCE TO ADOLESCENT ENGLISH LANGUAGE LEARNERS

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The purpose of this research is to explore the changes that occur in non-western European student teachers' conceptions of the role of the teacher when teaching science to adolescent English language learners (aELLs). This research took place over the course of a one-year science teacher education program designed to prepare teachers to be advocates for educational equity. Concept mapping serves as the primary tool for detecting these changes over the course of the year.

Background

Past research on teacher education has focused on the outcomes of teacher education programs with little attention paid to the events and processes which ultimately shape student teachers' conceptions. (Merino, 1999) It has long been assumed that teacher education programs positively influence student teachers' conceptions of teaching and the role of the teacher, however little research exists on how these conceptions change throughout the program and how that relates to various aspects or components of the student teachers' experiences. This is particularly important when the student teachers are English language learners (ELLs) and the student teaching involves ELLs (Long, 1983; Merino, 1991; Merino & Faltis, 1993).

Student teacher achievement has been documented through various summative assessments including exit examinations, demonstration lessons and professional portfolios however little formative evidence exists which documents student teacher growth through the

duration of the teacher credential program. This research utilizes concept mapping as a method for detecting changes in student teachers' conceptions about the role of the teacher when teaching science to aELLs. No evidence exists in the research literature that this method has been utilized to look at how non-western European-American student teachers think about teaching aELLs.

As the student population in the United States becomes more ethnically and linguistically diverse, it becomes important to study methods for insuring educational equity for all students regardless of their cultural or linguistic heritage. Many people believe that one way to address the learning needs of aELLs is to prepare more teachers who are from non-western European-American backgrounds, however, past efforts to keep pace with the increasing diversity of the classrooms have failed to meet this need (Merino & Faltis, 1993). Every year, the linguistic and cultural heritage of the student population is less like that of the teachers in their classrooms (Fueyo & Bechtol, 1999). For that reason, this research focuses on the experiences of three non-western European-American science student teachers as they participate in a one year graduate level science teacher education program that focuses on preparing teachers who are: 1) Investigative about their practice, 2) Reflective practitioners, 3) Collaborative members of a learning community, and 4) Advocates for educational equity.

Literature Review

As secondary education moves into the twenty-first century the lay public is calling for greater teacher diversity to meet the educational needs of culturally and linguistically diverse students. Despite significant changes in educational goals, science content, and diversity of student populations over the past 150 years, the process for selecting and preparing teachers has changed little from practices used in the early 1900's (Goodlad, 1990; Haberman, 1996). Many

teacher education programs have failed to substantially alter their basic training formats to prepare teachers to address the specific learning needs of the students they will teach (Korthagen & Kessels, 1999). Preparing new science teachers to meet these changes in student population and to raise science achievement for all students defines the goals of science education and science teacher education programs. Three reform documents guiding science education, *Science for All Americans* (Science, 1993), the *National Science Education Standards* (Council, 1996), and *Scope Sequence and Coordination* (Aldridge, 1996) were prepared with the express purpose of meeting these goals. These documents call for an active inquiry oriented, engaging approach to teaching science that de-emphasizes the assimilation of isolated facts and emphasizes developing inquiry skills, habits of mind, and the integration of the disciplines of science. Despite their wide spread acceptance in the science community, inquiry based teaching ideologies may prove difficult for student teachers raised in non-western European cultures. According to Fradd and Lee (1999) many non-western European student teachers view the role of the teacher as the transmitter of knowledge based on their personal educational experiences. For non-western European-American student teachers this view of teaching is in conflict with the "teacher-as-facilitator" role described in the science education reform documents (Fradd and Lee, 1999). The conflict between the culture of the student teachers' early schooling and the inquiry oriented teaching student teachers are asked to use, forces student teachers to "cross boarders" (Atwater & Brown, 1999, p. 46) between two educational cultures.

Clearly, the cry to provide more non-western European-American teachers to meet the needs of non-western European-American students needs more investigation. One of the primary questions to be investigated is how non-western European student teachers deal with the

conflict between their early educational experiences and the school cultures where they want to teach? What influence do the teacher education programs have on student teachers' conceptions and how do those conceptions change throughout the science teacher education program. Fueyo and Becthold (1999) caution that little evidence has been found linking teacher race-ethnicity and student achievement. "In fact, evidence exists that matching teachers and students by race and ethnicity may have a negative effect on student achievement" (p. 26). Fradd and Lee (1999) identify critical differences in instructional styles that inhibit non-western European-American teachers' success in an inquiry, constructivist based classroom. "Although they may understand their students, these [non-western European] teachers may be unfamiliar with current expectations for science instruction or the inquiry process" (p.14).

Understanding the relationship between prior experiences and the student teachers' conceptions of teaching science requires the development of tools capable of detecting these conceptions and the changes which occur over time. Historically, journal reflections and prompted writing assignments have been used for this purpose. Concept mapping, however, provides another method for detecting student teachers' developing conceptions about teaching. Through the use of concept mapping, those conceptions can be linked to student teaching experiences, and there by monitored across the yearlong program.

Initially developed by Novak and Gowin (1984), concept mapping is a method for representing students' conceptions in a two dimensional, graphical format that includes a hierarchical organization. On Novak style concept maps, students place the most general or important concept at the top of the map. More specific concepts or details are linked in a hierarchy of importance moving down the map until the most specific details and examples are at

the bottom. Each pair of concepts is linked by a verb or phrase describing their relationship. According to Novak and Gowin (1984) as the student teachers' conceptual understanding increases the number of concepts and the number of levels of hierarchy should increase.

Since it's introduction, concept mapping has been used as a planning tool (Hyerle, 1996; Edmondson, 1995), as an instructional tool (Heinze-Fry ,1990; Hyerle,1996a, 1996b; Markow Lonning, 1998; Mintzes, Wandersee, and Novak, 1997a; and Novak, 1995, 1993, 1990), and as an assessment tool (McClure, Sonak, and Suen., 1999; Mintzes Wandersee, and Novak, 1997b; Rafferty and Fleschner, 1993; and Rice, Ryan, and Samson ,1998). In addition, several authors have described the use of concept mapping as a way of exploring teachers' conceptions about science (Artiles, Mostert, and Tankersley, 1994; Dorough and Rye, 1997; Ferry, 1996; Gess-Newsome and Lederman, 1991; Hoz, Tomer, and Tamir, 1990; Mason, 1992; Mergendoller and Sacks, 1994; Novak, 1995; Rink, French, Lee, Solmon, and Lynn, 1994; Trowbridge & Wandersee, 1994; Wandersee, 1990; White and Gunstone, 1992), however, the use of concept mapping to detect changes in student teachers' conceptions about teaching science to aELLs has only recently been explored by the author (Pomeroy, 2000).

Methods

This research presents a qualitative study of the changes that occurred in three non-western European-American student teachers' conceptions of the role of the teacher as they progressed through a one year science teacher education program focused on preparing teachers to be advocates for educational equity.

During the orientation to the science teacher education program and prior to entering the classroom, the supervisor/researcher provided concept map training including creation of a

sample map on a topic unrelated to this research topic. The procedure for concept map training described by Novak and Gowin (1984) was used for the training. Four times during the credential year, the student teachers were asked to draw concept maps depicting their conceptions of teaching science to adolescent English language learners. These concept maps, created at the beginning of the program and at the end of each academic term, represent the primary source of data for this study. The supervisor/researcher's biweekly classroom observation notes and end of term interviews offer additional contextual data for the analysis. It should be noted that the researcher also served as the student teachers' supervisor throughout the program. This relationship, allowed the researcher to create rich descriptions of the student teachers' overall teacher credential program experience.

This research was guided by the research question: How do non-western European-American student teachers' conceptions of the role of the teacher when teaching science to aELLs, as reflected in their concept maps, change over the course of a one year teacher education program?

Over the course of the one year science teacher education program, student teachers completed four *de novo* concept maps in response to the prompt "Knowing what you do about teaching and learning, draw a concept map of your thoughts about teaching science to adolescent English language learners." The first map was created prior to the student teachers entering their student teaching placements. Subsequent maps were completed in December and March with the final map completed in May at the end of the science teacher education program.

The concept maps were analyzed for changes in structure and content throughout the year. Interviews were conducted after completion of the second, third, and fourth map. During

the interviews, the student teachers were asked to reflect on their maps and describe their thoughts about the content and structure of the maps, and any changes they observed between the maps. Bi-weekly observations of student teaching were conducted and the observation notes were used to provide context for the changes observed in the student teachers' maps.

Data

Program

The student teachers that form the focus of this research, Cesar, Fateh, and Helene, were enrolled in a one-year science teacher education program that included coursework on pedagogy, and teaching methods as well as a full year of student teaching in one class. The focus of the program was on preparing teachers to meet four roles:

1) Teacher as investigator- throughout the science credential program, students were encouraged to look critically at their work. These investigations include teacher research projects and case studies.

2) Teacher as reflective practitioner- Through the use of reflective journals, writing prompts and video taped lessons, student teachers were encouraged to think critically about their teaching.

3) Teachers who are collaborative members of a learning community- Student teachers are encouraged to work closely with their cooperating teachers, their instructors as well as other members of their cohort to maximize their student teaching experience.

4) Teachers who are advocates for educational equity- Throughout the science teacher education program student teachers are encouraged to learn and apply strategies and beliefs that will insure equal access to a high quality education for all students including ELL.

Emphasis on these roles permeated all components of the program including the State mandated

course work required for Cross Cultural Language and Academic Development (CLAD) authorization, plus all methods classes and student teaching (See Table 1). The program focused on preparing student teachers to address the unique learning, cultural, and emotional needs of second language learners.

Table 1

Science Teacher Education Course Work

Quarter	Classes
Fall	Cultural Diversity in Education Teaching Secondary Schools Teaching Physical Science in Secondary Schools Teaching Language Minority Students in Secondary Schools: Methods and Research
Winter	Reading in Secondary Schools Teaching Secondary Schools Teaching Life Science in Secondary Schools
Spring	Educating Children with Disabilities Computers in Education Teaching Secondary Schools

Whenever possible, student teaching placements were arranged in schools with significant aELL populations to insure student teachers had opportunities to work with language minority students (See Table 3). Due to school site scheduling, the number of second language learners in each student teachers' classrooms varied from a low of one to as many as ten. The normal student teaching load for participants in the science teacher credential program included a year long placement in a class matching their subject area specialty plus a second semester placement

in a science class at a different school or different grade level. Typical pairs of placements are shown in Table 2 (See Table 2)

Table 2

Typical student teaching placements by major

Student teachers' major	Year long placement	Second semester placement
Biology	Biology	General science Integrated science Middle school science
Chemistry	Chemistry	Integrated science General physical science
Physics	Physics	Integrated science General physical science

Table 3

Demographics of Schools used for Student Teaching Placements

School	Student Population	% English language learner
Donaldsville High School	1000	17%
Howard High School central	3100	24%
Howard HS Satellite	900	30%
Leopold MS	1100	24%
National High School	1400	3%
Viceroy High School	2000	5%

(Language census summary statistics, 2000)

Students

Cesar

Cesar was born in Mexico and moved with his family to the United States at the age of 13. Cesar reports that he had been in school in Mexico until he moved to the U.S. and that he was working at grade level. Though he spoke no English upon his arrival, Cesar completed high school by the age of eighteen and enrolled in the major research university that forms the context for this research. Throughout high school, Cesar participated in educational outreach programs, being the first person from his high school to participate in university programs designed to promote college attendance by second language learners. Cesar majored in physics and earned a BS degree during the summer prior to entering the teacher education program. Prior to entering the teacher credential program, Cesar worked as a tutor in a college outreach program for incoming freshmen.

Cesar was placed in a college preparatory physics class at Viceroy High School (See Table 3) for his yearlong student teaching placement. This class consisted of 32 students including one ELL from Germany. Through out the first semester, Cesar also worked in his second semester placement classroom, a ninth grade physical science class of 28 students including five ELLs. In his physics class, Cesar utilized a teacher-centered instructional strategy consisting of lecture, problem sets, activity, review and test. Each week was structured the same with little variation between weeks. The activities that Cesar used were provided by the cooperating teacher and were designed to validate the information in the lecture and problem sets. Cesar's preferred instructional strategy was mathematically based with every activity concluding

with mathematical problems. At the request of the cooperating teacher, Cesar's student teaching placement was terminated at the end of the first semester. This request for termination was made by the cooperating teacher based on his concerns that the students in Cesar's class were falling behind the other physics classes and that they would not receive an equitable physics experience by the end of the school year. Throughout the first semester, the supervisor conducted biweekly observation visits to Cesar's classes and weekly planning meetings with Cesar and the cooperating teacher. During the post observation conferences and the planning meetings the supervisor offered suggestions about teaching strategies, planning, lesson ideas and activities. Near the end of the first semester, Cesar began making progress on including different teaching strategies however the cooperating teacher's request was honored to give Cesar an opportunity to work in a more ethnically diverse school.

For the second semester, Cesar was placed in a 9th grade physical science class at Donaldsville High School with two ELLs (See Table 3). Cesar struggled to establish classroom control and develop coherent lesson plans for this class throughout the first half of the winter quarter. Despite weekly visits from the supervisor and weekly meetings with the cooperating teacher these struggles continued throughout Cesar's second student teaching placement . At the request of the cooperating teacher, Cesar's placement was changed in mid-March to a small 10th grade biology class that contained seven ELLs. Cesar continued to struggle with classroom management with the biology class and the cooperating teacher requested that Cesar stop student teaching by the middle of April. Due to the late date, no other placements were arranged for Cesar for the remainder of the year.

Cesar struggled with the credential program coursework, maintaining a C+ average. He received grades of incomplete in two of the five classes during the fall quarter as well as grades of incomplete in one methods course in the winter quarter and another during the spring quarter. The incomplete grades in the winter and spring quarters were due to Cesar's inability to complete classroom projects and observation assignments.

In early spring, Cesar returned to his hometown and spoke to his high school teachers about his goal to become a physics teacher. Despite his limited progress in the teacher credential program, Cesar was offered a job teaching physics beginning in the fall of the coming school year. At about this time, Cesar's preparation for his student teaching diminished exacerbating his struggles with classroom management.

Cesar's concept maps developed from unorganized eclectic collections of concepts in August to a focus on teaching strategies in May. A common attribute of all four maps was Cesar's attempt to link all concepts together. His August and December maps, showed a semblance of hierarchy, however, this structure is completely abandoned by the March and May maps. During interviews, Cesar commented that he felt that mapping was confusing. This confusion was evident in the structure and content of his August and December maps. By March and May he had abandoned the traditional hierarchical concept map structure entirely and instead attempted to represent his conceptions in other ways. The March and May maps resembled concept webs or wheels (Hyerle, 1996b) with the key concept located in the center of the map and all other concepts radiating out from this center. Cesar continued to attempt to connect all concepts together through a variety of linking strategies. In the March interview, Cesar described the structure of his March map by saying, "I tend to do things in circles, I can

make any combination of these two. . . I've always been thinking about things in cycles" (Interview with Cesar, March 2000). By March, and again in May, the content of the maps focused entirely on teaching strategies. On the May map, Cesar created cyclical maps with curving lines to show motion, ". . . it tells me movement and that's what I'm basically showing here . . . movement and changes" (Interview with Cesar, May 2000). The content of all of Cesar's maps, described his conceptions of teacher centered teaching. On each map, Cesar described things that the teacher could do to teach subjects and provide knowledge as opposed to strategies that teachers could use to facilitate learning.

Fateh

Fateh was born in Algeria and earned his B.S. and Ph.D. degrees in that country. He did post graduate research in England prior to obtaining a similar position at the research university that forms the context of this study. Before entering the science teacher education program, Fateh's classroom experience was limited to short, one or two day, demonstrations of plant physiology in area high schools. When Fateh interviewed for the science teacher credential program, he commented that he knew very little about American schools and he wanted to be sure that he would have opportunities to learn about school organization as well as teaching strategies.

Fateh's yearlong placement was a 10th grade integrated science class at the central campus of Howard High School, a large, urban high school (See Table 3). In this class of 31 students, the second language learners spoke Spanish, Cantonese, Mien, Vietnamese, and Russian. Fateh's second semester placement was at the Howard High School satellite campus. In this placement,

Fateh taught biology to 34 students including 12 aELLs. The demographics of both Howard HS campuses were similar.

Throughout his yearlong placement, Fateh utilized a teacher-centered approach to teaching,. He planned all of his lessons in a format that allowed him to deliver content to the students. When describing his December map, Fateh identified this approach to teaching when he said, "This is teaching science. It's a way of delivering knowledge. . . and that's what it's about, teaching science. And the knowledge can be received. . ." (Interview with Fateh, December 1999).

Fateh's concept maps revealed this emphasis on "teacher–as-knowledge-transmitter" (Fradd and Lee, 1999) throughout the year. Like Cesar's maps, Fateh's August concept map is confusing with a large number of linkages between multiple concepts. His focus begins with concepts about the varying levels of students' language ability. He divided the students into English language learners and others and subsequently divided the English Language learners by levels. He then suggested different types of concepts he felt were appropriate for the different language levels. By December, Fateh had moved away from classifying the language levels of the students and adopted an organizational scheme that included different teaching strategies as the primary concepts. In the December interview, Fateh referred to these different strategies as ways that students could receive information from the teacher, "you hear what you receive, . . . from the teacher" (Interview with Fateh, December 1999). On the March map, Fateh returned to dividing students by their level of language achievement as the primary organizers. On this map, he suggested that he was thinking of ways that aELLs could receive support and assistance but he ultimately returned to the same teaching strategies as the concepts that he described in

December. Fateh's May map again focused on teaching strategies that the teacher could utilize to deliver content to aELLs.

Throughout the first and second semester, the cooperating teacher for the yearlong placement and the supervisor worked with Fateh about alternative methods for delivering content and the curriculum. Emphasis was placed on encouraging Fateh to engage students in critical thinking and inquiry lessons. Fateh did not utilize these suggestions to engage his students in the integrated science class. Throughout the year, Fateh maintained his belief in teacher directed learning in both classes. His maps revealed a "teacher-as-transmitter-of-knowledge" philosophy of teaching, as revealed through the types of strategies he lists on concept maps, through out the year.

Helene

Helene was born in Cameroon and attended local village schools until departing for college. She was trilingual in her primary home language, French, and English. She commented that the language she learned in her early school years was based on oral traditions and that her early exposure to written language was "British English." Upon completion of her Ph.D. in Agronomy, Helene taught in a middle school in the north central United States as a substitute teacher during the 1997-98 school year. During her interview for the science teacher credential program, Helene commented that she was looking forward to learning more about teaching in California schools. She commented that her experiences as a substitute teacher had provided her with some classroom experience but that she was anxious to learn more about how teachers organized their instruction and planned their lessons.

Helene's yearlong placement began in an environmental science class at National High School (See Table 3), which contained three English language learners. This placement was changed at the end of the fall quarter as a result of the cooperating teacher's request for maternity leave. For her second semester placement, Helene taught seventh and eighth grade integrated science at Leopold Middle School (See Table 3). The Leopold science curriculum included several school wide instruction units for both the seventh and eighth grades students during the winter and spring quarters. As a result, Helene had limited choice on the content of her teaching during these pre-planned units of instruction.

Helene's maps reflected a strong emphasis on both language acquisition and teacher directed instruction. Much like Fateh's maps, Helene's early maps appear slightly unorganized and failed to adhere to the concept map structural guidelines described previously. All of Helene's maps focused on students' levels of language ability and how teachers could assess student learning. She utilized these concepts to organize her thoughts about the types of teaching strategies to use with second language learners. All of Helene's maps concluded with the concept of frequent or regular assessment, a concept that grows in importance from August to May. This was indicative of Helene's emphasis on the teacher's role as transmitter of knowledge when teaching second language learners and was confirmed by observations of Helene's teaching at Leopold MS. In both her seventh and eighth grade classes, Helene's lessons focused on the transmission of information from the teacher to the student. She frequently gave notes and lectures followed by multiple assessment strategies to determine her students' levels of understanding. Helene's view of the role of the teacher and her emphasis on student learning can be summed up by her comments in the May interview when she said, "I was focusing on the use

of teaching techniques that would increase learning in ELL students" (Interview with Helene, May 2000). Though not as clearly stated as Fateh's or Cesar's, Helene's emphasis on the "teacher-as-knowledge-transmitter" role was supported by observations of her teaching and her use of frequent assessment to determine that students "got" what she was teaching.

Analysis

This research was designed to answer the research question: How do non-western European-American student teachers' conceptions of the role of the teacher when teaching science to adolescent English language learners, as reflected in their concept maps, change over the course of a one year teacher education program? In addressing this question, it is clear that Cesar's, Fateh's, and Helene's conceptions about teaching science to aELLs, developed in both depth and breadth through the course of the year. Each participant added significantly to their original August maps, however, their perspectives on the role of the "teacher-as–transmitter-of-knowledge" remained stable.

Cesar

Through the course of the year, Cesar systematically distilled his conceptions for teaching aELLs from an eclectic unorganized set of conceptions to a more focused statement about the teaching strategies which he believed were appropriate for teaching aELLs. Along the way, he abandoned the conventional concept map structure in an effort to more closely depict his true feelings. Through this distillation process, Cesar maintained a view that all his conceptions about teaching science to aELLs were connected, that the process was cyclical and dynamic, and that the teacher's role was that of the "transmitter-of-knowledge." Given Cesar's student teaching experiences, these changes are understandable. By the time he had completed the March map,

Cesar had changed student teaching placements three times, and he had received an offer to teach regardless of whether he completed the science teacher education program. Without classes to relate his developing conceptions to, Cesar's May map focused on teaching strategies, the one thing he had control over. Furthermore, he did not develop conceptions related to students' experiences, backgrounds, or the school environment which Fateh and Helene described in their March maps.

Fateh

Changes in Fateh's conceptions, as described on his concept maps, differed from the changes demonstrated by Cesar. Where as Cesar's concepts became more focused in one specific area, Fateh developed two foci, vacillating between students' language abilities and the teaching strategies necessary to address those abilities. The conceptions about students' language ability, represented on the March map, demonstrated a considerable synthesis of the nascent concepts listed on the August map. The teaching strategies focus of the December map reemerged on the May map revealing changes in the breadth and depth of Fateh's conceptions about teaching science to aELLs. Through both iterations, Fateh maintained the "transmitter-of-knowledge" focus on the role of the teacher as he described in his December interview.

Helene

Helene's maps remained the most stable from August to May. Her primary focus on all four maps was the differentiation between English language learners and English speakers and the types of teaching strategies that were appropriate for aELLs. On the March map she included the influence of the school as the entity that directed the curriculum however, these concepts did not reappear on the May map. In her interview, Helene commented that the mandatory, school

wide, curriculum and the mandated State testing which occurred during the spring were not always best for the aELLs because they disrupted students' learning. After detailing her conceptions about the school district's influence on aELLs, Helene returned to the language abilities of the students and the teaching strategies appropriate for the science curriculum as seen on her other maps. Helene's May map included references to collaboration with teachers of other subjects as yet another way to meet the needs of aELLs. This increased emphasis on collaboration reflected one of the four emphases of the science teacher credential program. Finally, Helene's maps all concluded with frequent or regular evaluation as a way of teaching aELLs. Through her interviews, Helene revealed that she believed that frequent evaluation was a way to control the delivery of content and to monitor students' progress. This approach describes a very "teacher-as-knowledge transmitter" view of science education.

Despite the differences in the types of changes in student teachers' conceptions, there were two areas where Cesar's, Fateh's and Helene's maps were similar. All three student teachers' maps focused on the role of the "teacher-as-transmitter-of-knowledge" and contained similar alternative concept map structural attributes. This orientation towards "teacher-as-knowledge-transmitter," described by Fradd and Lee (1999), is very common for non-Western European students. Fradd and Lee describe this feeling when they say, ". . . classroom interaction patterns may be more comfortable when they resemble those of the students' home culture. Teachers from cultures where they are expected to exercise authority and serve as knowledge-givers may feel comfortable with a direct, explicit approach [to instruction]" (p. 16)

Finally, all three students described the initial task of concept mapping as confusing. Despite two hours of training on creating concept maps and completion of one practice map, all

three maps, created in August, displayed distinctively non-Novakian structures. Common to all three maps were "gathering links" which connected multiple super-ordinate concepts to a single subordinate concept. This, plus student teachers' efforts to link all of the concepts together, gives an impression that all of these student teachers think holistically not linearly or hierarchically.

Conclusions

It is clear that the student teachers' concept maps revealed their growing conceptions of teaching science to aELLs and that those growing conceptions were similar in terms of the student teachers' view of the role of the "teacher-as-transmitter-of-knowledge." It is also clear that non-western European-American student teachers' conceptions of the role of the science teacher are very stable. Though the sample size of this study is too small for generalization, it appears that much of the change in student teachers' conceptions of teaching science to aELLs can be attributed to the student teaching experiences and the science teacher education course work. However, these same experiences had little impact on the student teachers' conceptions of the teacher's role as described by Fradd and Lee (1999).

Implications

This research suggests that as the science education community strives to increase the number of non-Western European science teachers it must be cognizant of the perspectives on teaching that future, non-western European, teachers bring to the classroom. Programs that emphasize inquiry and constructivist teaching strategies must realize the existence of potential conflicts between non-western European student teachers' conceptions of teaching and the goals of the *National Science Education Standards*. Many non-western European student teachers

hold deeply ingrained conceptions of the teacher's role as the "knowledge-transmitter" based on their early educational experiences. Efforts must be made to identify the variety of instructional conceptions that teachers bring to the classroom and to help student teachers determine when each is appropriate.

> The influence of teachers' backgrounds and prior experiences with science is embedded in decisions about what constitutes instructional effectiveness. Teachers who share the languages and cultures of their students often have background knowledge relevant to their students' needs and interests. When carefully accessed, such knowledge can promote meaningful learning opportunities. (Au & Kawakimi, 1994; Trueba & Wright, 1992;Villegas, 1991; cf Fradd and Lee, 1999, p. 16)

Decisions about appropriate instructional strategies must consider the students' backgrounds, the class content, and the student teachers' experiences. Programs must be cautious about promoting an "inquiry-fits-all" philosophy of science education. This is particularly the case when student teachers work in classrooms with aELLs. Care must be taken to value all conceptions of education and the role of the teacher to insure equal access for all students to a quality education.

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CALIBRATED PEER REVIEW IN GENERAL EDUCATION UNDERGRADUATE HUMAN PHYSIOLOGY

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During the past decade, a broad body of research has validated three key principles of learning: (1) students come to the classroom with preconceptions, including misconceptions that persist until the learner confronts these shortcomings, (2) deep understanding requires a broad foundation of factual knowledge organized within a context, and (3) metacognitive approaches that encourage students to establish an internal dialogue improve learning (Bransford, Brown, & Cocking, 1999). Nationwide, initiatives such as the National Science Resources Center project LASER —Leadership and Assistance for Science Education Reform— are being implemented to help teachers align science instruction with these principles. California State University Fullerton belongs to one of eight regional LASER consortia aimed to improve science education through a science leadership program for teachers.

Science education reform initiatives like LASER run into problems when teachers model instruction on their own undergraduate coursework (Bransford, Brown, & Cocking, 1999). In response to this and other problems, the National Research Council established a Committee on Learning Research and Educational Practice to identify areas of concern for future research (National Research Council, 1999). Among the concerns was a call to examine current instructional practices at the undergraduate level. Human physiology is an undergraduate course with great potential for providing a foundation of integrated science content within a context that teachers can connect to students – through curiosity about the human body. But instructional practice using the traditional textbook approach to teaching physiology seriously conflicts with

the three key principles of learning, and studies have identified misconceptions that persist across many age groups in spite of instruction (Arnaudin & Mintzes, 1985). Graduate Schools of Medicine are beginning to show interest in problem-based learning to incorporate the principles of learning into physiology instruction, but not much work has been done to improve the instructional approach used to teach undergraduate human physiology.

Problem

Human physiology at the undergraduate level is generally taught without regard for the key principles of learning. More than two decades have passed since David Ausubel (1980b) argued that physiology is taught from the perspective of transfer and retention of knowledge, a perspective that fails to encompass two of the three principles of learning: (1) that students hold preconceptions and (3) that metacognition empowers learning. Ausubel wrote that "long-term functional learning and retention of both basic science and clinical subject matter and their application to problem solving are the most effective means of promoting transfer" (Ausubel, 1980a).

Purpose

This project was designed to explore peer review of problem-based writing assignments as a mechanism to confront students with their misconceptions and to promote metacognition to improve learning of human physiology. A preliminary study was performed in an undergraduate human physiology course to test the following *Hypothesis:* Calibrated Peer Review^{TM} (CPR), a web delivered program that enables peer review of writing assignments, increases achievement on both essay and standard textbook multiple choice assessments.

Theoretical Perspective

The theoretical rationale for this hypothesis is based upon the cognitive structural view of knowledge. According to David Ausubel, "the cognitive structure itself, that is, both its substantive content and its major organizational properties, should be the principal factor influencing meaningful learning and retention in the classroom" (Ausubel, 1980b). Ausubel's perspective is similar to earlier writing about the organization of knowledge by Benjamin Lee Whorf (1956) who proposed a theory about the role of language in cognition. Whorf wrote that what is meaningful about experience can be thought of as "emergent from a field of causes that is itself a manifold of pattern and order" (Whorf, 1956, p. 269). A recent review of Whorf's views on language in thinking and learning clarifies his perspective. "The ability to isolate patterns and discriminate between them provides us with the basis for noticing the kinds of variation we have to be able to attend to in order to learn from situations and apply that learning to new contexts," and "learning is a matter of growing proficiency to isolate, abstract, combine, and recombine essentials in the same configurations as experts" (Lee, 1997). Writing assignments should be used as a tool for isolating and discriminating patterns that represent a student's construction of a cognitive structure of knowledge. Ausubel (1980) builds upon the cognitive structural view of knowledge to suggest designs for instruction, and he writes that meaningful learning could be accomplished

> *1) substantively*, by using for organizational and integrative purposes those unifying concepts and principles in a given discipline that have the greatest inclusiveness, generalizability, and explanatory power, and

2) programmatically, by employing optimally effective methods of ordering the sequence of subject matter, constructing its internal logic and organization, and arranging practice sessions.

Traditionally, learning in physiology has been assessed through written essays, a practice that encourages students to select unifying concepts and to organize and integrate ideas across levels and in a variety of systems as they study. However, dismal student essay responses are not unusual. If we accept Ausubel's perspective, poor essays may be due to our failure to "arrange practice sessions." Essay assessment without practice is unfair. Problem-based learning has been used to promote oral practice with the cognitive structure of knowledge in physiology, but individual accountability is a problem.

Methods

For this study, physiology concepts were taught using experimental problem-based learning activities followed by peer-review of practice essay assignments, each designed around some unifying concept or principle of physiology. "Problem-based learning" is defined here as "working on an unsettling, puzzling, unsolved issue that needs to be resolved." (Lynn, 1990). Calibrated Peer Review™ (CPR), a web delivered program that enables peer review of writing assignments, was used as a formative assessment tool to reveal student misconceptions, promote metacognition for reflective learning, and to encourage individual student accountability following each problem-based learning assignment (Chapman, 1999).

Finding a control for experimental instruction can present a problem. In this case, one class alternated between experimental and control treatments, with a research design that compared each student's results on both essay exam and standard textbook multiple choice question responses following the experimental instruction with their exam results on another set

of unifying concepts and principles that were taught using a traditional instructional approach. The traditional approach included lectures and some cooperative group work using textbook problems designed to exercise Bloom's higher order thinking objectives (Bloom, 1956). All published materials were from Silverthorn's Human Physiology textbook (1998). Frequent multiple choice quizzes were used as formative assessment and to encourage individual student accountability for learning concepts addressed using the traditional approach. The concepts taught with the problem-based tasks and CPR essays were not presented as lectures. Consequently, the independent variable was the problem-based tasks and CPR essays versus the lecture/cooperative group work instructional approach, whereas the dependant variable was student achievement as measured by both multiple choice and essay exam questions.

The physiology concepts taught using the experimental instruction included active transport and epithelial function, pressure, resistance and bulk flow, steroid hormone function, post-synaptic membrane potential and lateral inhibition of vision signals, and an integration lesson on genes and hypertension. The concepts selected for control instruction were comparably challenging and were selected to minimize overlap: diffusion and ion gradients, membrane potential and membrane depolarization, heart function and mean arterial pressure, hormone feedback control, and an integration lesson on control of blood volume and osmolarity during exercise.

Participants

Biology 310, Human Physiology, is a course for non-science majors that fulfills the upper division general education science requirement. Of 40 students who were enrolled in Biology 310 during the spring, 2000, four were excluded from this study. Three of those excluded failed due to non-participation, and the fourth student audited the course and did not complete all

assignments. About half of the students enrolled to fulfill degree requirements: 34% kinesiology majors, 11% pre-med (including nursing and dental), and 8% social work majors. The remaining students represented majors as broad-ranging as psychology (16%), speech, elementary education, and anthropology. All participants had completed a pre-requisite lower division Biology course. Participants included no freshman, but were 21% sophomores, 29% juniors, 37% seniors, and 13% graduate students. It should be noted that 39% of the student participants have families that primarily speak a language other than English (mainly Spanish), and 13% were themselves more fluent in a language that is not English. A language center and writing services were available to help all students improve their writing.

Delimitations and Limitations

The study was conducted during the spring semester, 2000. Both lectures and problem-based/CPR assignments were designed as the course progressed, since this was the first time this instructor taught this course. Results were blind scored and tabulated by a student assistant without knowing which scores corresponded to the experimental versus control instruction.

Data Collection

Quizzes of multiple choice questions published with the textbook (Silverthorn, 1998) and CPR assignments were used for frequent formative assessment throughout the semester. These results were not counted. Reported results are based on scores from summative assessment items on the midterm and final exams. These included multiple choice questions to assess learning of topics taught by both the experimental and the traditional approaches as well as instructor created essay test items for concepts taught with each instructional approach.

<u>Results</u>

The Main findings are shown in Table 1.

Table 1

<u>Mean Exam Sub-scores for Concepts Taught Using CPR versus a Traditional Approach</u>

	Midterm exam scores		Final exam scores	
	CPR	Traditional	CPR	Traditional
Multiple Choice	83(2)**	75(2)	82(2)*	76(2)
Essays	84(3)**	65(3)	80(2)	75(4)

<u>Note.</u> The values represent mean percentages of items correct. Numbers in parenthesis are SEM. Stars indicate scores that are statistically greater for CPR compared with traditional instruction, with ** $p < 0.001$ or * $p < 0.01$, Paired t test, n-36 for each measure.

Following three CPR assignments, the mean midterm essay scores were significantly better for topics taught using CPR compared with those taught using traditional instruction. At the end of the semester, mean total essay exam scores were significantly better for topics taught using CPR compared with those taught using traditional instruction. On the midterm test, mean scores on multiple choice items were significantly better for topics taught using CPR compared with those taught using traditional instruction.

Sample Assignment Results

The first of the six CPR assignments required students to synthesize information from a variety of sources into a description of compartments within organisms:

> Compartments allow organisms to maintain a variety of internal environments that are very different from environments outside the organism. Maintaining such internal environments is critical to homeostasis. Write a paragraph describing various walls and compartments at different levels of organization within the human body. Use these terms in your paragraph: cell membrane, cell junctions, epithelia, extracellular fluid, organ system, phospholipid, and vesicles.

Types of Mistakes

Twenty nine of the forty students revealed mistakes in their answers. Nearly all of the errors were due to erroneous relationships between concepts, and these were grouped and are exemplified as follows:

- Levels of organization (23 instances)

  Cells are molecules that are separated from the external environment and each other by membranes.

- Cause/effect problems (3 instances)

  Vesicles discharge their contents into lumens to keep external environment separated from the internal environment.

- Relationship not logical (8 instances)

  In tight junctions, movement of materials is not allowed past the cells, whereas in gap junctions, small molecules and ions can pass.

- Over-generalization of a relationship (4 instances)

Cells surrounding organs have a semi-permeable membrane.

- Stated relationship is wrong (4 instances)

  The extracellular fluid acts as a swimming pool with cells floating around in it.

A Possible Misconception

A possible misconception was identified from a frequent mistake in student thinking about vesicles, membrane-bound compartments within cells:

- Cells are responsible for bringing nutrients to other parts of the body through *vesicles*.
- Through the fluid cells can communicate and send things to each other through pouches called *vesicles*.
- Cells also use *vesicles* to transport proteins to other parts of the body.
- Cells are surrounded by extracellular fluid in which *vesicles* store and transport molecules to and from different cells.
- Within organ systems *vesicles* are used for storage and transport.
- *Vesicles* discharge their contents into the lumens to keep external environment separated from the internal environment.

Learning About Current Research

Another sample assignment shows how CPR was used to link learning to current research:

> A knowledge claim is a conclusion supported by valid data. What knowledge claims are reported in a testosterone research study by Urban et al, American Journal of Physiology 269: 820-6 (1995)? This activity has the following goals: Analyze a primary research article to arrive at valid conclusions and apply the conclusions in the real world. Compare

and contrast peptide hormones and steroid hormones. Explain the role of cell membranes in determining the difference in location and mechanism of hormone receptors.

Twenty of the thirty seven student responses show mistakes with relationship errors, with four that were similar to those that appeared in the previous assignment, and one new mistake that also appeared in subsequent assignments. These are exemplified as follows:

- Cause/effect problems (3 instances)

  Receptors are located inside the cell membrane because it is easier for proteins to bind on the receptor in the nucleus.

- Relationship not logical (4 instances)

  Injected testosterone increased mRNA in the elderly men, therefore an increase in muscle excitability occurred.

- Over-generalization of a relationship (5 instances)

  IGF-1 cannot enter the cell and needs testosterone to work.

- Stated relationship is wrong (2 instances)

  IGF-1 is a messenger hormone. The second messenger breaks down ATP into cyclic AMP.

- Wrong term for the concept (6 instances)

  Next, the process of transcription occurs in which amino acids transcribe into proteins based on a specific genetic code.

<u>Results Summary</u>

Six kinds of relationship mistakes appeared in most CPR writing assignments: levels of organization errors, cause/effect problems, relationship that are not logical, over-generalization of a relationship, wrong relationships, and a wrong term for a concept. In spite of the frequency

of these errors in the practice assignments, summative assessment results were better for topics studied using CPR. This result suggests that students learned from the peer review process, perhaps as a result of confronting the mistakes among each others' responses.

Eighty seven % of students reported that CPR was equal to or better than the end of chapter questions as a tool for learning physiology. When asked in an open question what worked best to help them learn the most challenging and complex concepts, 39.3 % of students listed CPR, 28.6% listed some form of visualization (textbook diagrams or video images), 25% listed graphic organizers like charts or concept maps, 21.4% listed case studies or personal experience, 21.4% listed talk with a study group, 10.7% described an experiment or simulation (even in this non-lab class), and 7.1% provided a mathematical equation.

Discussion

Calibrated Peer Review (CPR) was a surprisingly effective tool to improve student learning of Human Physiology. Results of this study show that CPR reveals common mistakes and improves student achievement on essay exams as well as on standard textbook multiple choice tests. Writing is an effective organizational and integrative tool for the purpose of meaningful learning, and peer review empowers the instructional context, perhaps by revealing possible misconceptions. With peer reviewed writing assignments, learning occurs (1) during writing, (2) while reading what others say, and (3) through self-assessment, thus instruction becomes aligned with the concepts of learning outlined in "How People Learn" (Bransford et al., 1999). With frequent writing assignments and peer review, the instructor is able to identify common mistakes in order to then engage the learners with interesting questions that address those problems. Mistakes that can be challenged include erroneous ideas about levels of organization, cause/effect relationships, and other logical relationships that must be recognized

as students apply or generalize new science knowledge. Research and current events related to the course content can be assigned to students through problem-based writing, making class discussion good and allowing the instructor to find out what resonates for particular learners. Future studies will aim to improve problem-based learning writing assignments and to identify problems that improve student attitudes toward science as they learn the complex foundations of physiology.

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THE SPACE EXPLORATION TEAM INQUIRY MODEL: LINKING NASA TO URBAN EDUCATION INITIATIVES

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Linking NASA Education Efforts

This paper describes how two different National Aeronautics and Space Administration (NASA) programs, one funded by the Office of Space Science (Code S), the other by the Office of Equal Opportunity (Code EU), teamed up with an outstanding high school science teacher to produce effective strategies to teach space science to inner city Latino high school students. The innovation arose out of a dialogue between a Jet Propulsion Laboratory (JPL) Science Educator, Richard Shope, and a National Board Certified High School Science Teacher, Dr. Lloyd Chapman at Garfield High School in East Los Angeles, about how space science proceeds at NASA/JPL and how students learn about space science in the classroom.

As a member of a flight project team at JPL, Shope has observed and participated in science and technology inquiry in NASA efforts to explore space. Chapman has intimate knowledge of the day-to-day challenges within the high school learning environment. Working together, Shope and Chapman modeled JPL's team approach to create effective instructional strategies that would:

1) Communicate the space science concepts called for by the tenth grade curriculum within a six-week time frame;
2) Give students a sense of the nature of science in the context of an authentic experience of how NASA/JPL conducts space exploration.

This resulted in the creation of the Space Exploration Team Inquiry model, a group science project instructional model that is of practical use to the high school science teacher and has broader implications in the teaching of the many disciplines of science and for the education of teachers of science.

University Preparatory Program

The Garfield High School students who participated in this action-based research belong to the University Preparatory Program (UPP) funded by NASA's Minority Initiatives efforts (Code EU), through California State University at Los Angeles. UPP targets motivated average to above-average Latino students interested in a pathway to a baccalaureate degree in the fields of mathematics and science. At Garfield High School, about eighty students per year enter the program at the ninth grade level and travel together as a cohort receiving integrated math and science instruction. The overall UPP goal is to provide support and encouragement to the participating students to apply successfully to enter the California State University system. UPP intervention includes meeting with science teachers, providing tutoring for students, and providing three experiences per year of visiting Cal State LA for a Saturday science workshop, but does not intervene directly into classroom practice.

NASA Education and Public Outreach

NASA's Office of Space Science (Code S) also funds science education development through the Education and Public Outreach programs of its flight projects, primarily in the form of creating curriculum support materials and conducting educator workshops for teachers in science on current space science exploration efforts. These mission-based programs are mandated to reach underserved, underutilized—and

underestimated—groups. At JPL, a multimission outreach testbed is used to research, develop, and implement effective programs. The effort is called Validating Outreach Innovations for Community and Education Services (VOICES), led by a consortium of Space and Earth Science missions, including the Outer Planets Program, Mars Program, Cassini, Galileo, Stardust, Deep Impact, Ulysses/Voyager, Earth Observing Missions, the Space Interferometry Mission (SIM), and the Deep Space Network. This instructional innovation was developed in the context of a VOICES program, *From the Outer Planets to the Inner City*, an urban education and public outreach initiative that explores ways to make a difference in inner city settings by engaging direct scientist, engineer, and science educator involvement, including direct intervention into formal classroom instruction and informal science learning opportunities.

The Space Exploration Experience at JPL

JPL is NASA's premier center for robotic space exploration missions. The selection of a mission begins as a dialogue between NASA and the space science research community. The science community recommends to NASA the scope of potential missions. NASA then offers competitive opportunities for participation in selected missions. Each mission consists of three fundamental components corresponding to the functions of science definition, flight project development, and communication of meaningful results. Each component's function is achieved by forming specific teams of experts.

The science definition team pulls together research scientists to focus and define the major science objectives of the mission. The flight project team brings together scientists, engineers, mission planners, and managers to solve the daunting technological

problems that are associated with the construction of a sciencecraft and accomplishing the science objectives through data retrieval and analysis. The science education and outreach team communicates the nature of the mission and the knowledge gained through the mission to the education community and to the public at large. From the inception of the mission, all of these teams work together toward a successful completion of the mission.

Bringing the Space Exploration Experience to the Classroom

The classroom scientific inquiry structure was framed by the ED^3U Teaching for Conceptual Change Model, a variation of the learning cycle developed by Dr. William McComas of the Center to Advance Science Education at the University of Southern California. ED^3U refers to five phases in a learning cycle approach: explore a natural phenomenon, diagnose prior knowledge, design personally-relevant tests, discuss ideas and evidence-based results, and use newly constructed knowledge.

Table 1 lists each component of the ED^3U teaching model and indicates the activities that we used to support each component:

Table 1

Space Exploration Team Learning Cycle Structure

ED^3U= Explore + Diagnose + Design + Discuss + Use

Explore a natural phenomenon: Space Science Concepts

- Guided student exploration, utilizing NASA/JPL images, mission data, web sites; demonstration of key concepts; text resources and classroom discussion
- Using mime, students explore Solar Nebular Theory of Solar System Formation
- In teams, students select and study specific space science concepts related to group space science projects

Diagnose prior experience: Space Science Concepts

- Assess prior knowledge through Concept Map and MIME Activities
- Concept Map: used to gain insight to current level of student understanding
- Concept-embedded MIME Activities: The Planet You, Build a Living Spacecraft

Design a personally-relevant test: Core Science Learning Objectives

- Groups, as Science Definition Teams, negotiate definition of core science learning objectives, develop area of interest within realm of Space Science
- Groups, as Space Exploration Project Teams, relate technology component of project (spacecraft & subsystems) in order to craft strategies to develop a mission and achieve science learning objectives
- Groups, as Science Education and Outreach Teams, devise ways to organize and interpret results and present newly constructed knowledge, using visual, multimedia, oral, and mime techniques

Discuss ideas: Space Science and Technology

- Share research ideas and related technology issues in context of working as teams
- Work out details of group science project ideas
- Teachers and Students are co-learners in the retrieval and analysis of research data
- Mindful of curriculum objectives, as concepts emerge in process of team participation during class time, Teachers intervene, through mini-lectures, class discussions, and assigned work, to seize whole group learning opportunities

Use knowledge in practice: Communication of Space Science Concepts

- Devise preliminary and final presentations, with emphasis on use of mime and dramatization techniques to enhance conceptual clarity
- Use multiple pathways of communication

Table 2 defines the roles of the teams in each of the components of the Space Exploration Team Inquiry instructional model in relation to the NASA/JPL space exploration components:

Table 2

Bringing NASA/JPL to the Classroom: Space Exploration Team Inquiry Roles

NASA/JPL Components	Classroom Components
Science Definition Team *Brings Scientists together in groups to:* 1. Reflect scientific curiosity negotiated in concert with science community. 2. Pose scientific questions that may contribute to new knowledge for science community and the general public; 3. Respond to space exploration priorities set by NASA that shape range of topics available for funding; 4. Define Core Science Objectives for NASA space exploration mission.	**Science Definition Team** *Brings Learners together in groups to:* 1. Reflect scientific curiosity negotiated in concert with teacher and team; 2. Pose scientific questions that may contribute to new knowledge for the class; 3. Respond to space exploration priorities set by curriculum that shape range of topics available for study, drawn from textbook, introductory activities (including MIME), classroom environment (posters, pictures, discussion, lectures), and the web; 4. Define Core Science Learning Objectives for space exploration project.
Space Flight Project Team *Brings together scientists, engineers, mission planners, and so on, to form a flight project team to:* 1. Research, design, and develop a mission that achieves core science objectives; 2. Design, construct, launch, navigate, and operate actual sciencecraft; 3. Retrieve, analyze, and interpret mission data, to construct explanatory generalizations and address scientific questions about space, leading to new cycles of scientific research.	**Space Exploration Project Team** *Brings Learners together to form a space exploration project team to:* 1. Research, design and construct a project that achieves the core science learning objectives; 2. Design, construct, launch, navigate, and operate actual space exploration project; 3. Retrieve and interpret information from existing resources, such as NASA/JPL data on web sites, contact with NASA experts, textbooks and class discussions, leading to new cycles of learning.
Science Education & Outreach Team *Brings together Scientists, Engineers, Science Educators to:* Communicate knowledge gained by the NASA space exploration mission in order to enable scientists, policy-makers, educators, students, and the general public to learn about and participate in space exploration.	**Science Education & Outreach Team** *Brings Learners together to:* Communicate knowledge gained by the Space Exploration Team to the whole class through written, oral, visual, multimedia, mime and dramatized forms of expression, in order to enable the other students to learn about and participate in space exploration.

Research Design

The innovation did not seek to introduce ways *to add on* to an already overburdened curriculum, but *to replace* the six-week unit with a group science project that was modeled on how space science is conducted at JPL. We hypothesized that curriculum content knowledge would emerge through multiple pathways from the context of each inquiry phase. At the outset, the JPL science educator expressed a greater confidence in this hypothesis than the science teacher. In fact, while willing to take the risk, the science teacher was initially quite skeptical of the possibility of covering all the material called for by the curriculum.

Assumptions

We assumed that the NASA/JPL Space Exploration Team Inquiry model is an effective instructional approach in the high school classroom. Components of the model had been used in prior settings to instruct teachers of an inner city afterschool science program, to provide activity ideas for teachers attending JPL educator workshops, and for direct instruction of elementary, middle school, and high school students in a wide variety of settings. The Garfield experience was the first time the model had been used as the primary vehicle of instruction. The science teacher was able to reflect on the difference between his standard approach and the innovation, because he was concurrently teaching another class covering the same subject matter without the innovation. The two groups were not, however, assumed to be equal, so the comparison was not structured to reflect a true experimental and control group.

Design Validity

The innovation was conducted as an action research process, with a class selected by convenience. The sample was small, functioning more like a case study. The innovation was accompanied by a variety of obstacles that required moment to moment adaptations. Some were typical of inner city settings such as a lack of internet access due to inadequate computer facilities, and trying to fit such a study into a busy JPL schedule, requiring flexibility on the part of the science teacher.

Variables

The science teacher devised a list of space science concepts that would be indicators of student success. We were interested in tracking student growth in attaining space science concepts. We assessed prior knowledge through use of a pre-test concept map. We assessed learning through video documentation of student projects and through a post-test that included an elaborated concept map, and three open questions:

1) What did you learn from your own group science project effort?
2) What did you learn from other students' group science presentations?
3) What did you learn from the book?

Based on these six strands of evidence we were able to form a picture of student progress related to the main components of the innovation.

Curriculum Content Objectives

Content emerged from the student group projects as they conducted research, asked questions, and presented ideas in class. The JPL Science Educator and the Science Teacher often seized teaching opportunities to bring focused awareness to science content and nature of science issues. In the standard approach class, content was presented in

sequence from the textbook through lectures, demonstrations, and activities led by the same Science Teacher.

Curriculum objectives and content were derived from the Science Links *Turn Left at Alpha Centauri* California State textbook, aligned with the National Science Education Standards (Science Links, 1998). Space science and technology concepts included, but were not limited to, the structure of spacecraft, the role of science instruments, the formation of the solar system, star formation, comparative planetary structure and environments, the solar nebular theory, nuclear fusion, gravity, gravity assists, comets, solar wind, aurora phenomena, photon emission, spectral analysis, and black holes. Sociocultural concepts included how to work collaboratively, the necessity to solve obstacles such as assuring that each group had email access, and the change in the traditional teacher-student role, where the science educator and teacher became co-learners with the students.

Initial Challenge: Bridging the Prior Knowledge Gap

The Space Exploration Team Inquiry model is designed to help both teachers and students to understand the processes involved in space exploration. The initial challenge is to provide a common base of shared experience that resembles the kind of common base that NASA's expert groups walk into the room with.

An actual NASA/JPL science definition team is composed of principal investigators who are leaders in their fields, familiar with the nature of science and the demands of evidence-based research. Flight project teams consist of a group of expert scientists and engineers who are already conversant with a broad range of technologies used in space exploration and are familiar with the leading edge of advanced technology

development. Education and Public Outreach teams must stay current with space science, advanced technologies, and be conversant with issues in the education of teachers in science, who ultimately communicate this knowledge to students in the classroom.

For example, a recent Discovery Mission proposal called Venus Atmospheric Measurement Probe, proposed a crucial experiment: a sciencecraft would enter the thick, hot Venusian atmosphere to measure the proportions of rare, inert, or noble gases (Argon, Krypton, Neon, and so forth) in order to compare similar measurements taken on Earth, Mars, and at the Sun. To understand why such a mission represents a crucial experiment and in turn excites space scientists and engineers, one would need prior knowledge of the nature of science and of the solar nebular theory, which explains the formation of the Solar System.

To introduce Garfield students to the necessary prerequisite knowledge, we prepared a kinesthetic mime activity. This activity engaged the students in acting out the solar nebular theory, a theory that explains how a supernova caused a cold and widely dispersed hydrogen gas cloud to collapse gravitationally to form a protosun, planets, and other objects—our Solar System. Thus in one 25-minute period we:

1. Introduced two nature of science concepts: the notion of a crucial experiment and the characteristics of a theory;
2. Created a common base of knowledge about the formation of the Solar System that would be applied throughout the unit; and
3. Engaged the students by getting them up out of their seats, moving around the room to float like a hydrogen gas cloud, then to explode like a supernova, to

collide, and to obtain angular momentum—a novel approach that set the tone for using mime as a kinesthetic inquiry tool throughout the unit.

Through a series of similarly structured learning experiences, students developed a range of competencies, including comprehension of content, engagement in space science concepts, and willingness to be more expressive in discussion and project presentation. Each phase of inquiry engaged students in the content and placed emphasis on the nature of science, mediated by the presence of the JPL science educator and the science teacher. Students also learned to explore and to utilize NASA and JPL web resources, including how to contact JPL scientists, engineers, or science educators in the context of furthering their project. Moreover, students learned to utilize a variety of approaches in creative, cognitive, and communicative dimensions to express space science concepts.

Movement Integration Mirroring Experience: The MIME Approach

The MIME Approach, developed by Richard Shope, applies the art of mime as a cognitive tool, especially to bring attention to how mime integrates concepts through movement experiences. Mime fosters a shared experience in the process of exploring a natural phenomenon that is normally inaccessible, intangible, invisible, or otherwise abstracted from immediate experience. By devising movement integrations as apt analogies, such physicalized expressions give students direct and vivid impressions of the content. Students are enabled to move toward an understanding of the actual phenomenon. The mimed actions engage the students in a context-rich experience that can translate into more conventional verbal and mathematical expressions of the conceptual content. For example, creating a mimed model of a gravity assist maneuver

requires the cognitive and physical awareness of the concepts involved. With the mimed experience as a base of comprehensible input, math and higher-level thinking extensions became easier to introduce.

Following a mime activity, the teacher and students can refer to the shared experience as a common source upon which to draw. It becomes a common reference point of shared prior experience. Modifying and manipulating the mimed model can also effect conceptual change. The power of the dramatic presentation style of the MIME Approach helps make abstract space science and nature of science concepts become lively and tangible. The kinesthetic component (mime) motivates high interest in the science content and evokes expression of science concepts in a way that can be authentically assessed.

Our use of the MIME Approach:

- Evoked a shared base of experience around key space exploration concepts;
- Connected concepts and allowed students to organize those concepts;
- Created concrete perceptual experiences that led to abstract conceptual understanding--making concepts more concrete and connected to experience, as opposed to fact-based and unconnected;
- Engaged students in a nontraditional learning mode that provided novelty;
- Provided a bridge of comprehensible input to move students toward higher-level math and cognitive thinking about space science concepts.

Results

Curriculum Coverage was Comparable

The textbook for the unit (*Left Turn at Alpha Centuri)* contained 65 concepts/vocabulary. The students expressed 45 of these concepts/vocabulary on their final exam. This indicates that 70% of the intended concepts were actually covered. This was comparable to the coverage over the same period of time in another class taught only through a more standard textbook, lecture, and discussion approach.

Students Learned from Each Other

Table 3 lists concepts mentioned four or more times in part of the final exam. The number of students mentioning these concepts is indicated in the parentheses after each concept.

Table 3

Space Science Concepts Learned by Students

From Own Group	From Other Groups	From Book	From Concept Map
Gases and Dust (11)	Black Holes (14)	Gravity (5)	Black Holes (26)
Hydrogen is red (6	Spiral into Black Hole (10)	Planets (5)	Nebulae (21)
Nebulae (6)	Survival Time in BH (7)	Rings of Planets (4)	Gravity (15)
Hydrogen and Helium (4)	Nitrogen Green Color (7)		Spectrum Analysis (11)
Planetary Nebulae (4)	Gases and Dust (6)		Star Formation (11)
Heat and Gas's glow (4)	Hydrogen Red Color (6)		Dust (9)
Black Holes (4)	Planetary Nebulae (6)		
	Cat's Eye Nebula (5)		

The Space Exploration Team Inquiry model demonstrated measurable student growth in content knowledge as well as enhanced affective attitudes toward science learning. By analyzing the frequency of the mention of space science concepts and viewing videotaped student presentations, the data showed that twice as many concepts were conveyed in contexts where students were learning from each other than could be

attributed to learning directly from the teacher or the book. The Space Exploration Team Inquiry model enabled much more frequent exchange among students.

Dramatic Altering of Teacher-Students Dynamic

The most dramatic results occurred in the arena of the complete altering of the group dynamics of the high school science classroom. While the JPL science educator and science teacher maintained their teacherly authority, they dropped their authoritative roles in the midst of the activities, and became immersed in interactions with the student Space Exploration Teams. Once motivated, the students are clearly placed in the driver's seat, demonstrating the confidence to inspire their own initiative and responsibility to complete their research and presentation tasks.

Here is one student's emailed thank-you note:

From: JR
Date: Sun, 25 Jun 2000 13:38:38 EDT
Subject: Thank you
To: Rick.shope@jpl.nasa.gov

Dear Mr. Shope,

I would like to thank you for making what I used to think was a boring science class into a fun one. I really felt like I was involved with the whole lesson and being involved helped me learn better and understand easier.

When you read something out of a book it gets boring and sometimes they use words you don't understand and you have to look up, so kind of side tracks you. It also made me feel like it wasn't just the teacher and the students but like we were all one whole. I really enjoyed you teaching our class and I really appreciate that you took time from your busy schedule to come teach us.

Sincerely, J R

Mime Enhanced the Learning Experience

The use of mime enhanced learning and generated an increased enthusiasm for science learning. The videotaped presentations demonstrated highly animated use of mime accompanied by explanation. It was through this medium that students reported

learning concepts from each other. Mime became a true educational tool, accessed by students to model and communicate space science concepts.

Implications for the Education of Teachers in Science

This action research study demonstrated the fruitfulness of modeling high school educational strategies after real world space science inquiry. Adapting JPL's scientific inquiry approach to bringing robotic space exploration missions to fruition proved to be an effective model for a space science education module. The interdisciplinary nature of space exploration, including space science, physical science, astronomy, physics, chemistry, astrobiology, life sciences, Earth science, and others, lends itself well to inclusion into the school curriculum in a variety of ways.

The use of mime enhanced students' abilities to communicate their learning. This study clearly demonstrated that mime was an effective tool in the learning process as most students reported on all the presentations in the components of their final exams.

We think that the Space Exploration Team Inquiry model with the incorporation of the MIME Approach deserves further study within the science education community. Of particular interest is the role that the classroom teacher plays in this learning process. In our case, the Science Teacher and the JPL Science Educator contributed to each group just like other student group members, by bringing relevant information that they knew or gained from research. This created a collaborative atmosphere in the classroom.

Thus, we plan to pursue more opportunities to create stronger studies that develop more data that will help us understand the breadth and depth of the application of two modalities, the Space Exploration Team Inquiry model and the MIME approach.

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IMPROVING UNIVERSITY SCIENCE AND ENGINEERING INSTRUCTION—A CASE STUDY OF AN ENVIRONMENTAL ENGINEERING LAB COURSE

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For decades there have been recommendations for universities to focus more on teaching as well as research (Davenport, 1970). Indeed, there have been recommendations for science and engineering courses to "sell" science to their students by making science interesting, appealing, and painless, without compromising quality of instruction or rigor of understanding (Reinarz, 1991). Many articles and books focus on appropriate strategies for effective university science teaching (Abraham, 1988; McKeachie, Chism, Menges, Svinicki, & Weinstein, 1994; Pickering, 1985; Schamel, & Ayres 1992; Terry, 1993; Tinnesand, & Chan, 1987). Even so university science teaching tends to remain in a traditional mode of teacher delivering instruction while the students remain passive recipients of information (Caprio, McIntosh, & Koritz, 1989; Woodhull-McNeal, 1989). This traditional instruction tends to alienate some students who may otherwise enjoy the creativity and challenge offered by science and engineering (Dickie & Farrell, 1991; Dickinson & Flick, 1996, 1998; Tobias 1985, 1990, 1992).

One of the constraints to a university's focus on teaching is the emphasis on scholarly research. Scholarly production in the form of refereed journal publications and research funding are expected for retention and promotion. Juggling the limited resource of time to do well in both teaching and research has been a major challenge for beginning faculty members in a research university (O, Brien, 1998). Indeed, it has been questioned whether most universities have a choice between teaching and research. Many new faculty have little or no teaching experience prior to the start of their university positions (McDermott, 1990; Reinarz, 1991; Shea

& Taylor, 1990). Additionally, the traditional methods that most university instructors use to teach their students appear to be a mismatch with what students actually need to develop strong understandings of the course content (Dickie, & Farrell, 1991; Dickinson & Flick, 1998; Tobias, 1985, 1990, 1992).

Another constraint to a focus on teaching at the university level is the view of teaching held by academic teachers. There is evidence that other university faculty members look with disapproval at other faculty members who focus on teaching (Dickinson & Flick, 1998). Additionally, some university faculty members hold a conception of teaching that makes it more difficult to change their teaching strategies. Samuelowicz and Bain (1992) found five different conceptions of teaching: from Level 5, imparting information, Level 4, transmitting knowledge, Level 3, facilitating understanding, Level 2, changing student conceptions, and Level 1, supporting student learning. It seems that many faculty members' conceptions of teaching are currently at Level 5, imparting information, and Level 4 transmitting knowledge. It may be easier to adapt and change teaching once a university faculty member is convinced that teaching is more than just delivering information at Level 5 or 4. On the other hand, it has been stated that "research is necessary for good teaching because only scholarship keeps a teacher alive. Professors who are good at research try to be good at teaching." (Davenport, 1970). Thus, it is not our contention that research should take second place to teaching, but that a balance be made between research and teaching, and that support systems be in place to help new faculty improve in their teaching as well as research efforts.

So, what is a faculty member to do once there is recognition for a need for improvement in teaching, while retaining a strong research agenda? That will be the focus of this study.

Method

The present study aimed to help a college engineering professor improve his instruction in an environmental engineering graduate lab course. He was a second year assistant professor in Civil and Environmental Engineering who expressed a desire for help in improving his teaching. He was not pressured to improve his teaching, but simply wanted to be better at teaching. He found he had several constraints that inhibited his teaching ability, (a) lack of teaching experience, (b) severe time pressure, and (c) pressure to enliven his class to encourage more student enrollment. To help him overcome these issues, he asked the first researcher, an assistant professor in science education, to intervene with some strategies for effective science teaching. His goals for improvement included to (a) be better prepared for instruction, (b) make long-term plans for his course, (c) improve class participation, (d) provide more interesting learning experiences, (e) increase his repertoire of teaching strategies, and (f) use time more efficiently.

The specific question that guided the research was how could a second-year assistant professor of Environmental Engineering improve his teaching in these goal areas? A second question was how his teaching effort could support his research goals.

Participants

The present study spanned the spring semester at the branch campus of a mid-sized research university in the northwest. One section of Environmental Measurements, a required course in Environmental Engineering, participated in the study. The class was comprised of seven students, all obtaining a Master of Science degree in Environmental Engineering. Their ages ranged between 27 and 50, with a mean of 32 years.

Course Structure

The laboratory course was structured to meet the needs of the majority of students who were part-time students and full-time environmental professionals. It was structured to provide the students opportunities to gain technical skills in designing and implementing laboratory projects and to explore an area of interests that could develop into their master degree thesis.

The students worked on five projects throughout the semester. Laboratory techniques were taught as part of the projects. The first four projects were assigned. Students developed skills in project design, in error analysis and in interpretation of data. Each student wrote a report on his/her work, which could improve his/her writing skills. The four projects also gave the students opportunities to generate data for a funded research project. The fifth project gave them the opportunity to study topics related to their interests.

Procedure

The investigation was interpretive in nature. Data collection spanned the entire spring semester during which the study was conducted. Several data sources were used to answer the question of interest. The first author was a researcher from science education. The second researcher was also the course instructor. The third researcher viewed and videotaped each class session for the first researcher's transcription. This allowed for the development of an initial baseline of teaching strategies. Additionally, teaching notes, the course syllabus, and other course materials were collected for analysis. Four of the seven students were interviewed for their perceptions of the assistant professor's instruction prior to and after interventions. Not all students were interviewed because not all students were available for interview. The assistant professor was interviewed to determine his current planning and delivery methods and to discover his goals for his instruction. The course Lab Technician, a former high school science teacher, was interviewed for her impressions of the assistant professor's teaching. The Program

Coordinator, who was the assistant professor's supervisor, was interviewed to determine the amount of support new faculty receive in their teaching and for department teaching goals. A similar sample of students and the assistant professor were interviewed post-instruction for their views at the conclusion of the semester.

At midterm the assistant professor was interviewed using a stimulated recall protocol to gain insight on his thinking in instruction. One of his videotaped course sessions was played for him and stopping points were selected at which to ask him questions regarding instructional decisions he was making. Additionally, he was asked to stop the video at any point in the interview to share information regarding his instruction. He did not choose to stop the video.

An additional source of data was a researcher log kept by the first author. The researcher log noted the interventions taken at each step of the study, and perceptions of how the professor may or may not be changing his instruction.

Interventions

Several interventions took place during the course of instruction. The initial intervention was comprised of the assistant professor and the first author discussing initial findings from course observations and interviews with students, the assistant professor, laboratory technician and program coordinator. A consistent theme identified was difficulty with organization of class sessions and goal setting. Thus, the first author conducted a mini-lesson on lesson planning. The assistant professor was asked to write an outline for his class sessions so he had a plan for each class, and knew his objectives for the day. Samples of the first author's own course syllabus and daily outlines and lesson plans were given to the assistant professor as examples of how he could write his outlines and define his own course goals. Following this intervention, the assistant

professor continued writing outlines for each of his class sessions throughout the remainder of the semester.

The second intervention asked the assistant professor to read a selection from *Teaching Tips* (McKeachie, Chism, Menges, Svinicki, & Weinstein, 1994), a book designed to improve college teaching. The reading selection's focus was questioning strategies and grouping strategies. He was asked to select at least two questioning strategies and plan some questions by writing them out and trying them in his class, then discuss with the researchers his reactions to using the strategies. The purpose was to help him increase class participation, one of his goals.

The third intervention was for the assistant professor to read *Beating the System* (Dickinson & Flick, 1998) and write a list of comments or reactions and discuss them with the researchers. The intent of the reading was to provide the assistant professor with some background information about problems in college science teaching, and some ideas for improving his own instruction.

The fourth intervention was given at the stimulated recall interview session and consisted of asking the assistant professor to write specific course goals he wanted his students to meet. The researchers encouraged the assistant professor to state the course objectives in his syllabus so his students would know them and be able to anticipate what they might learn in the class.

The fifth intervention was for the assistant professor to read an article on conceptual change teaching strategies (Posner, Strike, Hewson, & Gertzog, 1982) and to react to it in writing and share his ideas with the other researchers. Conceptual change strategies were raised at the stimulated recall interview as a reason to ask more open-ended questions—to determine students' prior knowledge on which to base further instruction. It was hoped that the reading

would provide the assistant professor more insight into reasons to continue with his work toward open-ended questions and give him a new instructional strategy, another of his goals.

Data Analysis

The first and third researchers analyzed the data. This approach was taken because the second author may have perceived the results as partially evaluative.

The data analysis followed an interpretive approach (Bogdan & Biklen, 1992; Taylor & Bogdan, 1984). The interviews, course syllabus and lesson plans, classroom observations and transcriptions of teaching videotapes prior to any interventions were analyzed to develop a profile of the assistant professor's general teaching approach. Following the interventions, the stimulated recall interview, post-instruction interviews, and transcribed classroom observations and videotapes, and researcher log, were analyzed to determine any changes in teaching approach that may be attributed to the interventions. Though the classroom observations were the primary data source, the researcher log and interviews provided additional information and allowed the researchers to triangulate data sources, protecting the validity of the study.

After all data sources were reviewed, categories were generated. Initial categories included items such as "disorganization," and "lecture." The categories were checked against confirmatory or otherwise contradictory evidence in the data and modified accordingly. Several rounds of category generation, confirmation, and modification were conducted to satisfactorily reduce and organize the data. Finally, pre- and post-intervention teaching approaches were compared from classroom observations and video transcriptions to assess changes in the assistant professor's general approach to instruction.

Results

Results show that the assistant professor improved in his teaching and ability to connect his teaching to his research obligations over the course of the semester, while there was still room for more improvement. It was clear that he began with the viewpoint of teaching with a Level 5 approach (Samuelowicz and Bain, 1992), imparting information. The sections below present evidence and descriptions of his teaching approaches before and after intervention. All names used are pseudonyms.

Pre-Instruction Strengths and Weaknesses

From interviews of students, the lab assistant , and program coordinator, it was apparent that the assistant professor's greatest strength was in being personable with his students. The students reported being comfortable approaching him and asking questions when they were confused. Below are some representative quotes from students:

> His strength is his good communication with students, and good personal contact with students. (Albab, pre interview)
> I think he is easy to approach and that makes all the difference. It is obvious that we are valued. It adds to it that we are allowed to ask questions. He says 'hi' to us in the halls, he is available to talk with. In other classes you are intimidated to talk, but not with him. (Mark, pre-interview).

While the students appreciated his strength at being personable with students, the laboratory technician questioned whether that really helped his teaching. She believed he tried to get by on personality and did not really have a good teaching strategy:

> He has a good heart, but that has nothing to do with being a good teacher. He has a good intent, but you cannot be a good teacher by personality alone. He needs help with being a better teacher. (lab assistant , pre-interview).

On the other hand, the program coordinator thought that with some support the assistant professor's rapport with students could be used that to his advantage in improving his teaching. The program coordinator admitted that currently there was no support system set up in his

department to help new faculty improve their teaching. Indeed, there is no university system set up for faculty development in teaching. The program coordinator, however, was supportive of the assistant professor's attempts for change in his teaching, though the program coordinator maintained he would be keeping a watchful eye to see how the change affected the department program:

> It does mean a lot that he is trying to improve his teaching. There is a lot of difference between a good teacher and a good lecturer. But it is still scary. One of the problems with being a program coordinator is you have to be careful where to interject yourself. You have to let the instructors take the lead in what they are doing. I understand and support his change, but I will be watching to see the effects. Without a support system set up in our department I am curious how he will improve his teaching. His course evaluations will show us.

It is interesting that the program coordinator valued the course evaluations as a major measure of good teaching, given that course evaluations are simply reports from students on the course and instructor. However, it is also true that the assistant professor received the highest course evaluations he had ever received for the current class. These course evaluations were above the departmental average.

The ability to be approachable to students seemed to permeate the entire semester, not just the early part of instruction. If being personable was the assistant professor's strength, it was evident through interviews and observations that being disorganized was his greatest weakness. Becoming better organized and better at time management was one of the assistant professor's personal goals. This disorganization initially hindered his ability to plan lessons and be prepared for the lab and lecture sessions. He noted that his greatest weakness is "planning a class session. I am more concerned with getting a lecture prepared than goals or planning." It is interesting that the students noted his disorganization, and wished for an improvement to help them gain more from the class:

> I would suggest he improve his organization. I am curious how he plans things. Sometimes it seems so disjointed. We don't know what the goals are for the course, where we are heading each class session. We need some kind of structure to organize us. (Rob, pre-interview).
>
> I think his only weakness is his disorganization. That is something he could do better. Each class is three hours long, and I don't want to waste any time. It would help to keep us on track. (Mark, pre-interview).

Indeed, both the program coordinator and lab assistant recognized the need for an improvement in organization as well:

> He is a disorganized individual—just look at his office. I think he would go a long way in developing some organizational skills in improving his teaching. It would make ideas easier for students to attain (program coordinator, pre-interview).
>
> He is very disorganized. I don't think there is a goal in mind, or a path, or if there is it hasn't been communicated to the students. He could use some help with preparing and planning in advance of each class. Sometimes he decides something on a whim and I have great difficulty in getting the materials he needs for those labs. If he would give me a syllabus I could prepare the materials in advance and have everything ready for each lab. (lab assistant , pre interview)

So, while it is easy to see that students, faculty, and staff alike found the assistant professor to be personable and approachable, they did note difficulties with his teaching and areas for improvement. It is important to recognize that all the different participants in the study had similar impressions of the instruction, pointing to the validity of the results. The next section will describe the assistant professor' approach to instruction prior to intervention.

<u>Pre-Intervention Teaching Approach</u>

The assistant professor's early approach to his class sessions could be termed a traditional lecture mode, which suggested that he was using the Level 5 view of teaching of imparting information (Samuelowicz & Bain, 1992). While he was open to students asking questions, he used a strategy of standing at the front of the classroom, delivering information while writing on the board. His typical pattern included giving students an overview of discussion topics for the class session and then presenting the information through a lecture. His disorganization showed through when he started a presentation of information in one direction, but went off in a tangent direction. Additionally, his disorganization showed when he shuffled through papers while at the front of the class, or forgot to bring supplies and needed to go back to his office to retrieve them. For example:

> Assistant professor: Does anyone understand eutrophication? (No one responded) It is basically when there is an overgrowth of algae or other aquatic plants at the

surface of water, leaving the deep water with little or no dissolved oxygen. (He used the whiteboard to draw an example, then shuffles through his paperwork searching for a lab report format sheet. He was unable to find it.)

In addition, he tended to use closed questions when he asked questions of students. Closed questions tend to inhibit conversations and interactions in the classroom. The questions he asked tended to have yes/no or right or wrong answers. Some examples are:

What is the method we use to measure contaminants?
What are the units we use?

The lab portion of the class for the first four projects could also be described as being a traditional lab, devoid of true scientific inquiry. The lab session generally consisted of the assistant professor demonstrating procedures that students were to use in that lab session. Then students completed their lab using the procedures the assistant professor provided. While the students appeared to be involved in the labs they were oriented toward following specific procedures given to them by the assistant professor. It could be argued that students need to learn specific approved procedures for scientific tests, but these procedures may be more appropriately learned within the context of an inquiry project.

Post-Intervention Teaching Approach

Changes in Instruction From Intervention.

The assistant professor began using the interventions suggested by the researchers in his instruction. Making time estimates is part of becoming organized and planned in instruction, so making the list and estimating the time was a first step in his session planning. He first started by trying to plan his lessons for each evening class. His plans were basically notes listing the items and order he would cover those items for each session. He tried to make time estimates, but they were often off. From his readings and discussions with the other researchers, he developed three new strategies that he implemented in his instruction, (a) more open-ended questions, (b)

allowing "think time" and writing time to respond to questions before responding orally in class, and (c) assigning more open-ended homework. In conjunction with point (b), the assistant professor called on non-volunteers for responses to open-ended questions because he knew they would have time to think and prepare a reply to the question.

An example of an open-ended question in a classroom setting follows:

> Assistant professor: Why are we concerned about soil contamination? (accepts all responses)
> Assistant professor: What are some different ways to do groundwater sampling?

Note that the questions do not require a yes/no, or right/wrong responses. Instead, they were designed to help students consider the issues and share their thoughts; as well as apply what they had gained from the course.

An example of the writing prompts he used to give students time to think about the issues in the class is below:

> Assistant professor: Write down the biological characteristics of soil, and why you think they are important for environmental engineers to know. I will give you two minutes.

After the two minutes passed he stated the question again, and recorded all student responses on the white board. The question shows his attempts to use an open-ended question, and to allow students time to think about what they are learning. In addition, writing down their responses requires students to be committed to their ideas, whether or not those ideas are shared in class.

Homework also began to focus more on open-ended ideas rather than simple right/wrong responses or solely computation problems. An example of a homework assignment is below:

> Brainstorm what you would think would be potential weaknesses for doing a plate count like this. You are taking organisms out of a soil and putting them in a material. What are the potential weaknesses—where might an environmental engineer be led astray. Just to give you some hints—there are a number of different media you can use, etc. Another perspective would be what are some

strengths. I know I didn't give you a lot of information, but I want you to brainstorm some ideas.

Changes in Instruction by Assistant Professor Without Intervention.

The assistant professor had planned three projects in advance of the course to help his students develop a better understanding of laboratory and research procedures. These projects were:

1. An irrigation water quality project relating water quality parameters to the type of irrigation canal tested.
2. A contaminated soil project focussing on the relationship of biological activity to soil contamination and other soil properties
3. A groundwater quality project focussing on charge balance of cations and anions in the groundwater.

Upon seeing the success of the projects in the course, and partially from his own desire for research, he decided the final project would be an open-ended, student-designed research project. This project would enable his students to truly experience an inquiry project, and apply what they learned to their own work. It would also hopefully align with the assistant professor's own research interests which would enable him to continue his own research focus. The structure of the course was changed to meet the assistant professor's new goals. Fewer laboratory techniques were covered overall in the class and less emphasis was placed on the chemistry involved with the analytical techniques. More emphasis was placed on designing experiments, data analysis and on sample collection methods.

Students designed their studies with input and advice from the assistant professor, received approval to proceed and then prepared a scope of work for their projects. The students

were given the opportunity to work alone, or as a team. The projects developed by the students were:

1. The measurement of ammonia solubility in high ionic strength solutions and it's impact on Hanford Waste Tank Issues.
2. The water quality associated with an irrigation outfall in the Yakima River.
3. The transformation of trichloroethylene (TCE) by zero-valent iron (team project).
4. Water quality associated with golf courses.
5. Water quality of the Touchet River and analysis of impacts on trout.

The students worked long hours in the field collecting the samples, in the lab analyzing their data and at home writing their reports. Following completion of their research studies, students submitted and presented their original research. Students had two opportunities to present their projects to others. The first opportunity was the first annual Students' Research Symposium, which the assistant professor and the first author suggested the university sponsor, and the second was an in-class presentation made by each student. The symposium gave the students an authentic arena in which to share their work. It was at the symposium, which was about two weeks before the final class session, that the value of the assignment became apparent. In fact, one of the students won the "Outstanding Graduate Student Project Award" for his class project. In addition, that same student followed up his original research with the full support of his employer. This paper also garnered the assistant professor some notoriety in that he was the second author of the paper, as well as the mentor of the student. Additionally, the project, student, and assistant professor, were the objects of a front page color news story in the local paper.

Two weeks after the Research Symposium, students made formal presentations in their final two class sessions. The formal presentations were similar to those one might see at a research conference. Following each student's presentation was a question and answer session during which students and attending faculty members probed for more details about the presenter's work. Students were very involved and interested in their peers' projects.

Post-Interview Perceptions of Instruction by the Professor and the Students.

As previously noted, the professor changed his viewpoint of teaching from Level 5 of Samuelowicz and Bain's (1992) scale of simply delivering information to the Level 3 view of facilitating understanding. At the post-instruction interview he even made a comparison of his original viewpoint of teaching to his current approach when he stated:

> I used to think of students as empty vessels I needed to fill with information. I am no longer concerned with passing along a certain amount of information, I am now trying to get students to provide good quality information that gets them thinking and truly understanding what they are doing. I am trying to use authentic projects to do just that. The course became more than just something to have to do. It became a possibility for interesting work to come out of it. Work that aligned with my own research interests.

One can see from the statement above that part of the key to the assistant professor's improvement in his viewpoint of teaching was his ability to note that teaching and research need not be mutually exclusive. By combining research with teaching he was able to help students develop what he felt were stronger understandings of the content he was to teach, as well as produce interesting work that met his own goals for research. As far as future goals, the assistant professor stated he wanted to continue using open-ended questions and assignments to encourage more student participation and authentic work to come out of his class. Other goals include becoming more organized and planned for teaching his future classes.

At the conclusion of the study the students in the course also had a positive viewpoint of the class and the instructor. They perceived changes in the class over the course of the semester. Some changes they noted were the assistant professor used (a) writing as a new strategy for responding to questions, (b) a new requirement for them to sit near the front of the class, and (c) questioning of all students, even if they weren't volunteering information.

Students recognized that the writing prior to verbally answering questions helped them sort out their ideas before responding. For example, Rob noted:

> He tried out some different things, like having us write answers down to help us think about our ideas. (Rob, post-instruction interview).

Students also noted that moving closer to the front of the room and closer to one another increased interaction among themselves and with the instructor. There was less distance perceived between the students and the instructor and a greater likelihood of participation in the class:

> He asks us to move forward and be closer to each other and to him. This makes the class participation greater than at the beginning of class (Albub, post-instruction interview).
> When he had us move to the front of the room we were more involved in the class than when we were spread out (Mark, post-instruction interview).

Students also noted that course participation improved through the use of open-ended writing questions that were followed by discussions. They were aware that the assistant professor had begun calling on all students, rather than only those who were volunteering responses. However, it did not seem to bother them because they were allowed to think about their responses before they were questioned publicly. He retained his image as an approachable, personable instructor:

> He asked questions of all of us—asked particular people rather than just "does anybody know?" We were more involved. (Mark, post-instruction interview).
> He has us write down responses to his questions for a few minutes, and then calls on particular people. We all have a chance to think about it first. He is very

personable and doesn't want to put us on the spot. (Rob, post-instruction interview)
I liked when he let us write down our responses to his questions. It helps because every student can think about the matter and tell his ideas. Then we can see if our ideas match other ideas of other students and see where we can change our ideas or thinking (Albub, post-instruction).

Students also valued the authentic research project. They noted that the research project gave them many opportunities beyond what typical lab projects would have given them. They recognized that they learned more by doing a personally designed study than had they done one assigned by the instructor:

> Any time you do a project on your own you learn better, so just reading can't be better than doing a project. And our project was a research project we designed for ourselves. If you do something on your own you really learn it. (Albub, post-instruction interview).

Students noted that the group project helped them use what they had learned in the laboratory exercises. It is interesting to see that students realized that actually applying the ideas to a novel, self-designed study helped them to recognize the purpose of the earlier laboratory activities and to really learn the procedures. It is evident that the authentic nature of the project served to provide a purpose for their learning and application of their knowledge:

> The research project was great. It made you start thinking about how you can put these things we learned to use, what kinds of tests to do, what kinds of data to collect. (Carl, post-instruction interview).
> It got me thinking about how I would use what I was learning, how I could apply it to more in-depth research, like for my MS thesis (Rob, post-instruction).

It was unanimous that the students perceived an improvement in his organization and course planning, but there was still a request for better organization and goal setting for the overall course and individual class sessions. In fact, students claimed to be able to tell when he had a thorough plan for the class, and when he did not. As far as suggestions for future improvement for the assistant professor the students noted that he still had room for improvement in organization.

Implications

It is apparent that both the assistant professor and students in the course felt major successes, but that there was still much progress to be made. The assistant professor still had problems with course and class session planning and goal setting, as well as an overall disorganized approach that left students confused at times. Additionally, he had difficulty understanding the article on teaching for conceptual change (Posner, et al, 1992). More support for his learning about conceptual change and its necessity should be given.

However, many things did improve in the assistant professor's teaching, and these improvements can provide important implications for university science education. First, the assistant professor sought change for himself. With his desire to improve and the external support he received during the semester, he was able to make important improvements in his instruction. These changes were questioning strategies, "think time" for students, increased class participation, and the implementation of an authentic inquiry project. The changes were achieved through the suggestions and support of the other researchers. In fact, the assistant professor himself noted that "without the support and reminding of use of open-ended questions it would be easy to fall back into the strategies I am accustomed to." Thus, it is important to note that even with the desire to change, without appropriate support, the change may not be as positive as hoped.

Thus, the second implication from the study is that a support system should be set up for all university professors who wish to improve their teaching. Again, it is unusual to find a university faculty member who has had any formal preparation in teaching prior to their first assignment at the university (McDermott, 1990; Reinarz, 1991; & Shea & Taylor, 1990). Without a support system that can share with them effective teaching strategies for their subject

matters it is unlikely they will develop such strategies on their own, or without much struggle and waste of their time. As one of the students interviewed noted "I wish all university faculty would improve their teaching. They might know their subject well, but that doesn't mean they know how to teach it." Without a support system for new faculty, or any faculty needing help, it is unlikely that they will even recognize the need for change. If they do note a need for change, it is similarly unlikely that any self-directed change will necessarily be positive or in line with national reforms (AAAS, 1993, 1992; NRC, 1996). However, the costs and resources for setting up such a system to help university faculty improve their teaching would be great, and thus it is prohibitive to set up such a system.

A third implication from this study is that faculty can be shown that teaching can support research, and research can support teaching. One of the keys for change for the assistant professor in this study was the recognition that research and teaching can be complementary. He found that when he instituted research projects in his course that his own research interests were supported. The assistant professor was able to be second author on students' papers and presentations, as well as featured in local news story coverage of his students' involvement in authentic research. One study even lead to a funded research project. Davenport (1970) agrees that research is necessary for good teaching. The combination of research and teaching in this course provided advantages for the assistant professor that not only improved his teaching, but also supported his research agenda.

A final implication from the study is that not only did the inclusion of the authentic research project provide advantages to the assistant professor, but also supported the learning of the students in the course. Students had an authentic project in which to use the laboratory procedures they learned, and were able to design a study that incorporated those strategies. In

addition, these students had a stronger understanding of the procedures and the purpose of doing them. They had conducted original research, some of which was the focus of local press, and some of which is still being carried on in MS projects and in their work settings. Thus, the course provided a setting for the seed of research to begin for many of the students involved. Courses that allow for student-designed research projects to be included help support student learning, understanding, and future knowledge of designing and carrying out original research.

Finally, the research in this study was carried out in a graduate course. Traditionally, graduate students have been expected to be more involved in original research than undergraduate students. What would be the effects on student learning for undergraduate students who were required to similarly design and carry out original research? It has been noted that undergraduate science and engineering instruction needs reform to help students develop strong understandings of content (Dickie & Farrell, 1991; Dickinson & Flick, 1998; Tobias, 1985, 1990, 1992). Perhaps inclusion of an authentic research project within undergraduate laboratory classes would help with the learning of content and for students understanding the purposes of learning that content. Future research should explore this idea. In addition, it has been noted that university faculty tend to "look down on" other faculty who teach introductory undergraduate courses (Dickinson & Flick, 1998). Would such perceptions change if the undergraduate students were producing authentic research projects that supported their professors' work? This is another topic for future study.

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CREATING AN INTEGRATED ELEMENTARY TEACHER EDUCATION PROGRAM: THE RESPONSE OF NINE CALIFORNIA STATE UNIVERSITY CAMPUSES

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Setting the Stage

It is not news that California is experiencing a severe teacher shortage. In 1997 California governor Pete Wilson instituted class size reduction. This limited class size to 20 in grades K-3. While a wonderful idea, the shortage of qualified teachers became immediately apparent! The state has thousands of emergency permit teachers in classrooms. The need for teachers to be quickly credentialed caused many debates. The cry was for better teachers, faster. While many would argue that you can't meet both demands (better AND faster), the California State University (CSU) system is trying to respond to that call. The CSU system is the largest credentialing source for the state, with 21 of its 23 campuses offering teaching credentials. In an effort to increase the number of qualified teachers the chancellor mandated that each campus

would develop an integrated or blended teacher education program. Specifically, this means that each campus would create a program that allows students to earn a credential concurrently with their bachelors degree. While not a novel idea, it marks a shift in thinking for California.

In 1970 the state of California stopped offering education majors. The rationale was that teachers would be better prepared if they majored in a subject area before entering a traditional fifth year credential program. This had a huge impact on the route that prospective teachers take, especially elementary teachers. Instead of a straightforward elementary education major the thousands of prospective elementary teachers select a major from the traditional menu of majors.

In response to that 1970 mandate, schools developed a major in Liberal Studies. This major was designed to provide prospective elementary teachers with the broad content knowledge they need to effectively teach. Students passing the major's required courses demonstrated to the state their subject matter competence (and therefore were not required to take subject matter competency exams). As a result of meeting state content requirements, the required coursework of the major tends to be fairly restrictive. This puts transfer students and late deciders at a disadvantage. For example, general biology for non-majors fulfills the life science requirement for Liberal Studies while other General Education biology courses, like marine biology or human anatomy, do not. This means that many students, transfer or late deciders, require longer than four years to complete the major. When the students do finish the major they must still complete a credential program in order to be certified. The credential they earn is a multiple subject credential and licenses them to teach K-8.

The challenge to integrate or blend content and pedagogy courses has been met in different ways on each campus. Some campuses decided to focus the integration in years three and four.

Their rationale was that transfer students would be enrolled at that point so the transition would be more seamless. Other programs revamped the entire liberal studies major resulting in a tightly packed four year sequence. This process brought together disparate groups of faculty on each campus. Science faculty started talking to elementary science methods instructors. Math and history faculty also began talking to their respective colleagues in education. Courses were cut, new classes designed and new sequences developed as campuses sought creative ways to get students through a Liberal Studies major and credential program in 4-5 years. A table summarizing the various campus responses to the mandate is found in Appendix A.

California State University, Dominguez Hills - John McGowan and Hedy Moscovici

What we have here is a Blended Liberal Studies/Teacher Education Program Combination. The program is designed for students, particularly instructional assistants in local schools and takes place in cohorts that allows for reserving places upon transfer and admittance. The program includes:

1. Community college transfer program that blends Liberal Studies degree and multiple subject (elementary) credential. The approved subject matter program waives Multiple Subject Achievement Test;
2. Six upper division semesters of subject matter and teacher education courses in year-round program. Includes integrated courses and option;
3. Introductory courses fulfilled at the Community College;
4. Early introduction to the teaching profession through multiple field experiences in local schools;

5. "Enriched" courses with basic skills (Title V), alignment with K-6 curriculum standards, and California Standards for the Teaching Profession;
6. Assistance with CBEST (California Basic Educational Skills Test)and other teacher preparation tests;
7. One semester of student-teaching in local schools;
8. CLAD or BCLAD certification.

There is a Math & Math methods course (already taught once), and an Earth Science & Science Methods course

The Blended Teacher Education Program at California State University, Fullerton - Amy Cox-Petersen, Teresa Crawford, Nancy Pelaez and Barbara Gonzalez

The Blended Teacher Education Program (BTEP) at California State University, Fullerton (CSUF) is a sequenced curriculum of teacher preparation that begins in the freshman year and provides early experiences in schools. The sequence of courses is designed for students to draw powerful connections between content areas such as math and science, and professional teacher preparation. This new program, which began in the Fall of 1999, differs from traditional teacher prospective teacher preparation in California in that BTEP students obtain a Bachelor's degree and a teaching credential within four years rather than enrolling in a fifth year. BTEP students complete 9 units of lower division science courses at CSUF then enroll in one upper division integrated science course, either SCED 410 Physical Science Concepts or SCED 453 Life Science Concepts and EDEL 430b Science Methods.

Faculty in the College of Human Development and Community Service and the College of Natural Science and Mathematics are currently revising SCED 410 and SCED 453.The revisions

will provide opportunities for students to pursue scientific ideas in more depth through inquiry-rich instruction using technology. The revisions will be designed to meet the CSUF upper division General Education requirement for extensive writing, while following the CSUF UPS 411.101 policy for 400 level courses that "provide depth of understanding or additional focus appropriate to the discipline," i.e., independent research and reference to primary literature. In addition, EDEL 430b will be taught as a co-requisite to support the BTEP students through the process of applying their experience with inquiry-based science learning as they develop and teach age-appropriate inquiry lessons in local elementary school classrooms. Science and education faculty will co-develop modifications of the three course to provide explicit connections between science content and pedagogy. New course components are outlined below.

New Course Components:

I. Interdisciplinary faculty will plan and teach theme-based, integrated science content for SCED 453 Life Science and SCED 410 Physical Science. Instruction will be presented in the context of rich science content, showing the interrelationships among science disciplines. SCED 410 will focus on space science and earth science: copper on earth and copper in the universe. SCED 453 will build on copper on earth but will also investigate copper in organisms. The theme of copper will be interwoven into each course to encompass developmentally appropriate, inclusive curriculum that is relevant to college student lives and that will promote continuous life long learning in science.

II. Faculty will model inquiry-based instructional approaches such as the learning cycle to promote conceptual change in preservice teachers' science knowledge. This will ensure that

students are active participants and inquirers and will enhance students' awareness of their prior knowledge and misconceptions.

III. Faculty will connect science content to other disciplines including math, geography and social studies, political science, writing and communications studies, and artistic expression. Students will use calculate data and findings, write and react to scientific investigations, and identify the sociocultural factors and implications related to scientific data and findings.

IV. Preservice teachers will read and discuss primary literature. Students will be required to read and react to articles related to current scientific research and advancements. They will access primary research and data as a source of knowledge.

V. Preservice teachers will participate in web-based instructional activities. Students will respond to primary research online on the course discussion board. They will access research sites such as Brown University's site that provides opportunities to identify and locate spectroscopic information (www.planetary.brown.edu/pds/about.html). *Frontpage* will be used as a public resource for students and the larger science community. *Blackboard* will be used as a private forum for class discussions and email communication.

VI. Preservice teachers will participate in scientific writing and reflection through the use of scientific notebooks/journals. Students will respond to scientific methods and content with questions and reactions related to class investigations, discussions, and assignments. They will provide evidence of science research and findings through science and mathematical reasoning, argument, and critical thinking.

VII. Preservice teachers will communicate with local scientists about current research related to course content. This will introduce students to real scientists and their work. Speakers will

include scientists at JPL who will speak about space science missions research and scientists from traditionally underrepresented groups. Communication will include class visits by scientists and by electronic mail correspondence.

VIII. Preservice teachers will participate in scientific data collection and analysis outside the formal classroom. They will determine copper content of the pond at the Fullerton Arboretum, copper in the water supply at the Fullerton Water Facility, and investigate copper in marine vertebrates at the Cabrillo Marine Institute. Students will develop research questions, then use integrated science and math process skills to collect, interpret, and report data and findings.

IX. Preservice teachers will participate in community service learning in local elementary science classrooms. Although SCED 410 and 453 will focus on a deep level appropriate for adult college students, preservice teachers will be required to work in cooperative groups to plan lessons that translate science content into teaching at the K-8 level. Preservice teachers will work collaboratively with local teachers to plan lessons that are aligned with the National Science Education Standards and California Science Content Standards.

X. Preservice teachers will participate in ongoing authentic assessment procedures including videotaped exit interviews as part of their final exam, self-evaluation of their own learning, and portfolios to demonstrate their knowledge and performance of science content, processes, and technology. These procedures are aligned with recommendations from the National Science Education Standards which claims that assessment should be authentic, include multiple measures, set in a variety of contexts, and with a focus on students' ability to inquire and understand scientific concepts, laws, and theories.

XI. SCED 410 and 453 will be offered as a co-requisite with science methods (taught in the School of Education) to support preservice teachers through the process of translating science content and pedagogy into classroom instruction in a local elementary school. Professors from science and education will work together to ensure its success.

Proposed Science Core and Concentration for ITEP, California State University, Long Beach - Alan Colburn and Laura Henriques

The following suggestions came out of discussions with CSULB science and education faculty, community college partners, local teachers and the science team leaders. Current liberal studies students shared their ideas about the attractiveness of this proposal. A proposed core and concentration are presented along with a rationale for their design. There are two cohorts of students currently enrolled in ITEP and the program has just gained university approval.

Required Courses for Liberal Studies Students to Learn Content Breadth and Pedagogy

Table 1.

Comparison of Science Core Requirements for CSULB Preservice Elementary Teachers.

Core Courses Before ITEP	ITEP Core Courses
BIOL 200 (4) General Biology	BIOL 200 (4) General Biology (ITEP designated lab sections)
GEOL 102/104 (3/1) General Geology & Lab	GEOL 106 Earth Science for Teachers with lab, includes more meteorology, ITEP students only
PHSC 112 (3) Introduction to Physical Science	PHSC 112 (3) Introduction to Physical Science
SCED 401 (3) A Process Approach to Science (Liberal Studies majors only)	CHEM 105 (1) Introduction to Chemistry (ITEP students only)
EDEL 475 (3) Teaching Science K-8 (part of credential program)	SCED 401 A Process Approach to Science (Liberal Studies majors only)
	EDEL 475 (3) Teaching Science K-8 (to be taken concurrently with SCED401)

Rationale for the Changes

GEOL 106 – Earth Science for Teachers, is an integrated lecture/laboratory sequence, focusing on general geology, astronomy, meteorology, and oceanography. The modifications in this course represent the changes to the California Science Standards (K-12).

Lab sections of BIOL 200 have been reserved for ITEP students. A set of K-12 application oriented activities have been developed for students which show how the concepts learned in lecture and lab directly relate to the K-8 curriculum. These activities are a supplement to the laboratory experience.

The new California Science Standards have a very strong emphasis on chemistry. The K-5 science standards are broken up into the physical sciences, life sciences, earth sciences, and investigation & experimentation. Grade 6 has emphasis on earth science, grade 7 life science, and grade 8 physical science. Grade 6-8 also has investigation & experimentation as a targeted area. "Physical Science" encompasses physics and chemistry. Even at the K-5 level there is a strong chemistry emphasis. The lack of chemistry in our current core is more noticeable with the newly adopted Science Standards. As a result, a new 1 unit chemistry laboratory course (CHEM 105) developed and taught by the chemistry department was added to the core. The course is hands-on oriented with special attention paid to both pedagogy and the content. This one unit chemistry course is one opportunity to blend content and pedagogy. There will be special training for teaching assistants involved with this class. The chemistry department and the science education department would work together to ensure that the course meets the blended standards of content and pedagogy. It is possible that single subject credential students would

help teach this lab-based course when the ITEP pathways are open to all Liberal Studies students.

SCED 401 and EDEL 475 will be taken concurrently. Students will be learning how to do inquiry based science and how to teach science at the same time. While the courses will not be team taught, the instructors will work closely so that the classes are closely aligned.

The Liberal Studies Science Concentrations (ITEP Science Concentration)

Prior to the development of ITEP, CSULB offered 14 concentration options for Liberal Studies students. The concentration is a 12 unit collection of courses in a single area. Less than 2% of the students chose science as their concentration. In consultation with Long Beach Unified School District it was decided to reduce the number of concentrations. Students must now choose between science, mathematics, language or social science. Not surprisingly, the number who select science is increasing.

The science concentration was remodeled to be attractive and as flexible as possible for those changing majors. The former concentration was very rigid. This meant that nursing students or physical therapy students who decide to teach elementary school could not use their science courses from their nursing programs towards a science concentration. Additionally, many transfer students have taken science courses elsewhere that meet GE requirements but not the Liberal Studies requirement (i.e. they don't articulate with the core courses). When appropriate, we tried to include those classes on the menu of courses in the concentration. Our rationale was that if a student has taken two classes elsewhere they'll only need one (or two) more for the concentration. Additional courses under development for the concentration include: (1) a field-based biology/geology/chemistry course, and (2) a course on evolutionary.

Two pathways for a science concentration were developed. Pathway A provides increased breadth of knowledge (additional courses in each area) while Pathway B provides increased depth of knowledge (multiple courses in a single discipline). The K-5 science standards are broken up into the physical sciences, life sciences and earth sciences, investigation & experimentation. Grade 6 has emphasis on earth science, grade 7 - life science, and grade 8 - physical science. Grades 6-8 also have investigation & experimentation as targeted areas.

Rationale for 'increased breadth' option is that elementary teachers teach all areas. Those that choose a science concentration should have more content knowledge across all disciplines. This might be most appropriate for the K-5 teacher. The rationale for an 'increased depth' option is based on the fact that a multiple subject credential is a K-8 credential. A student who wants to teach upper elementary or middle school would do well to have increased content development within a single discipline.

Proposed Science Concentrations

Table 2.

Pathway A: Increased Breadth Concentration Option

12 units minimum – choose one course from EACH column, plus additional units, if necessary, chosen from any area, or from NSCI 309I (Women and Science) or NSCI 375I (Science and Society)

GEOL 160 (Oceanography)	BIOL 153 (Marine Natural History)	CHEM 100 (Chemistry & Today's World)
GEOL 105 (Field Laboratory experience)	BIOL 100 (Biology & The Human Environment)	ASTRO 100, 100L (Astronomy)
GEOL 300I (Earth Systems)	MICR 101 (Introduction to Human Disease)	PHYS 100A (General Physics)
GEOL 190 (Environmental Geology)	MICR 300I (Human Immunology: in self-defense)	CHEM 111A (General Chemistry)
GEOL 240 (Historical Geology)		

Table 3.

Pathway B: Increased Depth Concentration Option

12 units minimum - choose three courses from a single column, plus additional units, if necessary, chosen from any area, or from NSCI 309I (Women and Science) or NSCI375I (Science and Society)

GEOL 160 (Oceanography) GEOL 163 (Science Of The Atmosphere & Weather) GEOL 190 (Environmental Geology) GEOL 240 (Historical Geology) GEOL 300I (Earth Systems & Global Change) GEOL/BIOL 303I (Coastal Systems & Human Impacts)	BIOL 153 (Marine Natural History) BIOL 100 (Biology & The Human Environment) MICR 101 (Introduction To Human Disease) MICR 300I (Human Immunology: In Self-Defense) GEOL/BIOL 303I (Coastal Systems & Human Impacts)	ASTRO 100, 100L (Astronomy) PHYS 100A (General Physics I) PHYS 100B* (General Physics II) CHEM 100 (Chemistry & Today's World) CHEM 111A (General Chemistry I) CHEM 111B* (General Chemistry II) CHEM 202 (Survey Of General & Organic Chemistry) CHEM 302

* these courses have prerequisites of a first semester course of same number

Summary: Science/Science Education Changes for Integrated Teacher Education Program (ITEP), Multiple Subjects Credential (MSC) at California State University, Northridge - Barbara Hawkins and Gerry Simila

Table 4.

Comparison of elementary teacher preparation programs at CSU Northridge.

Regular Liberal Studies Waiver Program	ITEP Liberal Studies Waiver Program

PS 196: Physical Science for Elementary School Teachers

- 4 units
- Lab + Lecture; lab and lecture can be separated in time, by hours, semesters, years; instructors are usually different
- pre- or co-requisite: Math 210 (mathematics for elementary school teachers; 4 units)

BS 100: Biology for Elementary School Teachers

- 4 units
- Lab + Lecture; lab and lecture can be separated in time, by hours, semesters, year; instructors are usually differents
- pre- or co-reauisite: Philosophy 196; Logic, 3 units

ES 300: Earth Science for Elementary School Teachers

- 4 units
- Lab + Lecture; lab and lecture can be separated in time, by hours, semesters, years; instructors are usually different
- pre-requisites: PS 196, Math 210

PS 196: Physical Science; 4 units

- Lab + Lecture; lecture and lab are blended
- co-requisite: Math 210; i.e., students will take PS 196 and Math 210 during the same semester
- co-requisite: LS Seminar 197a (see following)

LS Seminar 197a; Math, Science and Technology

- 3 units
- This seminar is co-taught by the professors from
  PS 196 , Math 210, and aprofessor from Elementary Education. It is a content seminar emphasizing math, science and technology, and has a fieldwork component that requires students to incorporate what they are learning into the elementary school classroom. The Education instructor provides very basic methods instruction as it relates to PS 196, Math 210, and technology, and supervises fieldwork.

Biology 100: Biology for Elementary School Teachers

- 4 units
- Lab + Lecture; lab and lecture taken in the same semester
- co-requisite: Philosophy 196; Logic, 3 units
- co-requisite: LS Seminar 197b (See following course)

E ED 580M: Math and Science Methods

- 3 units; i.e., 1.5 science methods, & 1.5 math methods

Math 310: Mathematics for Elementary School Teachers

- 4 units
- required i*n addition to Math 210 for teacher candidates without the MSAT waiver*
- upper division, and can be taken anytime in junior-senior years

LS Seminar 197b: Ways of Knowing

- 3 units
- This seminar is co-taught by professors of Philosophy of Science and Elementary Education. It is a content seminar, emphasizing logic, critical thinking and ways of knowing. It has a fieldwork component that requires students to apply what they are learning in the elemenrtary classroom; specifically, students examine children's explanations in the classroom. The Education Professor acts a liaison between the course content and its application to the classroom, and supervises fieldwork.

ES 300: Earth Science for Elementary School Teachers

- 4 units
- Lab + Lecture; lecture and lab are blended
- co-requisite: Math 310 (in addition to Math 210, required mathematics for elementary school teachers without MSAT waiver; 4 units)
- co-requisite: E ED 475; Math Methods

E ED 470: Elementary School Science Methods

- 2 units
- pre-requisites: PS 196, BS 100, Math 210, LS 197a,
LS 197b

E ED 475: Elementray School Math Methods

- 2 units
- pre-requisites: PS 196, BS 100, Math 210, LS 197a, LS 197b; E ED 470
- co-requisite: ES 300 & Math 310

The Blended Program at Cal Poly Pomona - Barbara Burke and Ed Walton

Background

California State University system has refocused attention on enhancing the quality of K-12 teachers. There is a search for ways to "blend" the teaching of "content" and "pedagogy".

The college of Education at Cal Poly decided to blend the "methods for teaching science" course in the education program with the science content courses. Liberal studies students who will be teachers are required to take one quarter each of chemistry, physics, and earth science They also take biology but they were not involved in the discussion.

We reviewed the state requirements for the methods courses. The objectives of the methods course were to be incorporated as much as possible into the three content courses. For example, interviewing a teacher of science, observing classes, sharing science with children, and knowledge of the science standards.

We spread the methods requirements into classes where they seemed to fit. Observations and science standards were handled in the geology course. Experience teaching children was part of the chemistry course. And, inquiry based learning was a feature of the physics course.

<u>The Blended Teacher Preparation Program at California State University, San Bernardino -</u>

Bonnie Brunkhorst and Herb Brunkhorst

Table 5.

<u>Comparison of Elementary Teacher Preparation Programs at CSU San Bernardino</u>

Science Liberal Studies Program Requirements-Before	Science Blended Program Requirements
Life Science One of the following - 5 units	Winter 2001 – Must Take
BIO 100 Topics in Biology	BIOL 100 Topics in Biology
BIO 201 Biology of Populations	
HSCI Health & Society: An Ecological Approach	
Physical & Earth Science – 9 units from one of the following course sequences	Spring 2001 – Choose One
	BIO 216 Genetics and Society
CHEM 100 Chemistry in the Modern World	BIO 217 Biology of Transmitted Diseases
Fundamentals of Chemistry – Atomic Structure and Chemical Bonding	CHEM 105 Chemicals in Our Environment
	CSCI 124 Exploring the Information

GEO 304 Geology in the Classroom
PHYS 304 Physics in the Classroom
One of:
PHYS 100 Physics in the Modern World
Basic Concepts of Physics
General Physics
CHEM 304 Chemistry in the Classroom
GEO 304 Geology in the Classroom
One of the following:
GEOG 103 Physical Geography
GEO 101 Introductory Geology
PHYS 103 Descriptive Astronomy
CHEM 304 Chemistry in the Classroom
PHYS 304 Physics in the Classroom
Special Topics in Science & Technology
BIO 216 Genetics and Society
BIO 217 Biology of Transmitted Diseases
CHEM 105 Chemicals in Our Environment
CSCI 124 Exploring the Information Superhighway
GEO 210 Earthquakes and Science Public Policy
Electives
CSCI 127 Introduction to Computer Technology for Educators

Integrated Capstone
NS 300 Science and Technology
NS310 The Environment and Human Survival
NS 314 Life in the Cosmos
NS 320 Energy
NS 325 Perspectives on Gender
NS 351 Health and Human Ecology
NS 360 Legacy of Life

Superhighway
GEO 210 Earthquakes and Science Public Policy

Winter 2002 – Must Take
CSCI 127 Introduction to Computer Technology for Educators

Spring 2002 – Choose One
CHEM 100 Chemistry in the Modern World
GEO 101 Introductory Geology
PHYS 100 Physics in the Modern World
Spring 2003 – Choose One
CHEM 304 Chemistry in the Classroom
GEO 304 Geology in the Classroom
PHYS 304 Physics in the Classroom

Fall 2003 – Choose One May not include the 304 course taken previously
CHEM 304 Chemistry in the Classroom
GEO 304 Geology in the Classroom
PHYS 304 Physics in the Classroom
Required Education Course
EELB 414 Science Curriculum and Methods in the Elementary School
Winter 2004 – Choose One
Integrative Capstone in the Natural Sciences
NS 300 Science and Technology

NS310 The Environment and Human Survival
NS 314 Life in the Cosmos
NS 320 Energy
NS 325 Perspectives on Gender
NS 351 Health and Human Ecology
NS 360 Legacy of Life

The CSUSB Blended Program is a Liberal Arts Subject Matter Degree Program that leads to a Multiple Subject CLAD Credential. The program is for full time, day students and is structured for completion in four years. The program blends content, pedagogy, and field experiences. The Standards-Based Program is emphasizes K-12 Content Standards and Interim Standards of quality and effectiveness for blended programs. The Interim Standards emphasize a concurrent, connected, and rigorous curriculum that has been developed collaboratively with P-12 partners and departments across the university. The program has a developmental focus, early advisement, and career exploration. The blended aspects of the program include, concurrent content and methods courses, sequenced content courses with a standards-based focus, and a coordinated field component. Other characteristics of the program include, supervision by content/pedagogy instructors within each content block, selected sites and field teacher involvement, cross-listed courses, student cohort, and an advising team made up of faculty from Arts and Sciences and Education.

<u>The Elementary Blended Program at San Diego State University</u> Cheryl L. Mason and Donna L. Ross

In general, the main changes are to incorporate field experiences earlier in the program, infuse cultural literacy throughout, and to model explicit, excellent instruction in all courses. The plans are detailed below.

1. Biology. Compare with traditional non-majors biology course. We will be using a new text and plan to pilot this at Mesa Community College in Spring, 2001.

- Overview: models excellent science instruction including multiple teaching strategies (discussion, case studies, pair-share, demos, lecture, hands-on lab, small group work, multiple assessment strategies, etc..), emphasizes the nature of science, identifies relevance to everyday life, stresses communication in science, infuses cultural literacy throughout the curriculum, and emphasizes scientific thinking and the Socratic method across topics and experiences.
- Science Processes and Skills: questioning, hypothesizing, collecting data, classifying, identifying patterns, alternate explanations.
- Teaching Skills: Makes strategies explicit and including this in all aspects of the course, such as assessment. Possible team-teaching. Analysis of videos of teaching situations and lesson plans.
- Concepts: History and nature of science, careers in science, cultural/sociological aspects to science, inquiry approach to science.
- Content Concepts: Physical and chemical properties of matter, energy flow and cycles, populations, natural selection, ecological principles, structure/function, heredity, ecosystem interactions.

2. Earth Science. Compare with traditional non-majors geology. This is in development now. We have a strong team with geology education faculty.

- Overview: This course will model excellent teaching, but will also begin to specifically address teaching younger students.

- Processes and skills: observations and inferences, estimation, measurement, classifying, patterns, technology, communicating findings, alternate explanations, evaluating evidence and data, inquiry approach, critical thinking.
- Teaching skills: questioning strategies, assessment strategies, diverse abilities and values, plan lessons.
- Concurrent field experience: observe science lessons, participate in "show me" geology lessons, analyze structure and purpose of lessons, identify teaching strategies, find and use resources.
- Concepts: cycles, geology, topography, water cycle, natural disasters, earth patterns, weather, astronomy.

3. Physical Science. This is essentially the same as the physical science course we now offer as part of the Liberal Studies major. The student interviews and infusion of cultural literacy will be the main change.

- Overview: This course will model a novel approach to teaching, including the use of technology, scientific modeling, and group processes. This course will incorporate innovative assessment strategies and focus on communication of scientific findings. Emphasis on scientific thinking in everyday life.
- Processes and skills: modeling, predictions and reasoning, inferences and revision of theories, variables, presenting and communicating findings, simulations, computer skills, collaboration.
- Teaching skills: make strategies explicit, interviewing children, analyzing and creating lessons.
- Concurrent field experience: interviewing children.
- Science concepts: motion and forces, light, magnets, electricity, energy, sound.

4. Science Themes. This 2-unit course is all new!

- Overview: This course will integrate life science, physical science, and earth science through several major themes. The emphasis will be on relevancy of science to everyday life, including policy making, voting, societal decisions, cultural issues, and daily choices.
- Processes and skills: use of resources, evaluating data, modeling, examining relationships, communicating, exploring alternate views of science, nature of scientific thought.
- Teaching skills: Less emphasis on actual teaching and more emphasis on the importance of scientific literacy for all.
- Science concepts may include: energy, cycles, change and homeostasis, population growth, evolution (still in planning stages--may use books such as Consilience: The Unity of Knowledge by Wilson)

5. Science Methods Course.

- Overview: This course will prepare students to teach science in the elementary classroom. The course will focus on pedagogy, resources, unit planning, etc... There will be less of an emphasis on content than currently found in 910C.
- Processes and skills: questioning, creativity in science, investigating testable questions, making inferences from observations, understanding variables.
- Teaching skills: Lesson and unit planning. Practice in good questioning strategies, using multiple teaching strategies, employing varied assessment strategies, integrating disciplines, finding professional development opportunities, exploring additional resources, implementing strategies for teaching to diverse learners (including English Language Learners), meeting standards. Course will include opportunities to teach science lessons to children.

- Science concepts: varied, as a context for processes, skills, and teaching strategies.

San Diego State Secondary Blended Program: Rethinking Science Teacher Preparation

Subject matter knowledge of teachers has four dimensions. *Content knowledge* is the traditional knowledge about the subject matter. *Substantive knowledge* includes knowing the key facts, concepts, principles, and explanatory frameworks in a discipline, while *syntactic knowledge* is the knowledge of the rules of evidence and proof within a discipline. These second two dimensions are sometimes referred to as *pedagogical content knowledge.* Finally, the fourth dimension addresses *teachers' beliefs* about the discipline. These beliefs are more important than many realize. As a result, our understanding and conception of the essential elements of science and mathematics is reflective in the manner in which we select and present scientific and mathematical concepts.

The issue, then, is not, *What is the best way to teach?* but *What is mathematics or science really all about?* To achieve our goals in science and mathematics education reform efforts, we must not provide a potpourri of unrelated and nonintegrated courses, but rather a developmental program that leads students toward an understanding of their disciplines and how the content is learned by others.

Our first objective is to design workable 4-year programs at the conclusion of which students receive both a bachelor's degree from the College of Sciences and a single-subject credential through the College of Education to teach grades 6-12. By creating 4-year baccalaureate/credential programs there will be an opportunity to recruit students and to provide a mechanism for letting them enter the teaching profession earlier than in the present program. Also, by making it possible for students to complete the degree and credential requirements in

four years instead of five, we hope to make the teaching profession more attractive to a wider variety and diversity of students.

For us, the opportunity to offer early field experiences in conjunction with the content courses is one that we believe will be most influential in attracting teacher candidates and developing career commitment. During the practicum students will develop teaching strategies that facilitate student learning of mathematical or scientific facts, techniques/procedures, concepts, principles, and problem solving skills. We envision that these experiences will involve far more than spending time in classrooms. They must also require analysis and reflection.

Through this type of integrated curriculum we expect students to develop pedagogical reasoning, that is. . .the process of transforming content knowledge into forms that are pedagogically powerful and adaptive to particular groups of students, (which) is at the core of successful teaching. Like pedagogical content knowledge, it is relatively undeveloped in novice teachers. Research evidence suggests that one of the most difficult aspects of learning to teach is making the transition from a personal orientation to a discipline to thinking about how to organize and represent content of that discipline to facilitate student understanding. Establishing more effective early field experiences linked with content courses will provide students with early opportunities to bridge the gap between content and teaching and help students decide early in their academic career whether or not they actually want to teach.

The possibility of a Fifth-Year Masters Degree Program, to be offered in conjunction with preparation for a Level II credential now being proposed by the California Commission on Teacher Credentialing, will also be explored. In addition, other alternatives will be considered, and perhaps implemented, such as working with the school districts to offer shared teaching

positions for the first two years of teaching during which the teachers team-teach classes. These teachers will concurrently enroll in a masters degree program.

Liberal Studies Integrated Teacher Education (LSITE) at San Francisco State University - Isabel N. Quita

The SFSU LSITE Program was developed and written by the Liberal Studies Program Coordinator, Helen Goldsmith and several other faculty members from the College of Sciences and College of Education. An LSITE advisor is from the College of Education. The sequence and description of courses presented here are taken from the Handbook: SFSU LSITE Program, updated 5/18/00.

There is no big difference in the actual courses offered by the regular Liberal Studies Program and the LSITE Program. The difference is in the sequence of courses. I will focus on the first two Interim Standards for Blended Programs of Undergraduate Teacher Preparation: Concurrent Curriculum and Connected Curriculum.

In response to Interim Standard 1: Concurrent Curriculum, SFSU's LSITE Program was designed to allow students to pursue a concurrent curriculum from the first semester they enter college as first-time freshmen. Students are admitted each fall semester as a cohort and enroll each semester in at least one course together. Each semester, students are required to spend time in an elementary classroom, both observing and participating (OP). Beginning with their first semester as freshmen, students identify themselves as future educators and are asked to think about what they are learning in their coursework in light of their future career.

As you can see from the attached curriculum plan, in their first semester, students enroll in 3 cohort courses (Elementary Education 646 - Seminar: Classroom Observation, ISED 150 - Orientation to Education, and Music 230 - Music for Elementary Teachers).

In the second semester, students enroll again in EED 646 as well as in Kinesiology 401. They continue to volunteer in an elementary classroom and are asked to incorporate some of the physical education concepts they learn in KN 401 into their work with children. At the same time they continue to take their basic general education courses.

The second year of the program was envisioned as a **science-oriented year**. In the third semester, students enroll together in Biology 100 and 101 so that they will become comfortable with hands-on science methods. Concurrence of subject matter and pedagogy occurs throughout the student's program. In their fourth semester, students study physical and life science coursework while at the same time enrolling in their first credential program course, EED 679. In this way, students will have an intensive year of science while at the same time applying what they learn in the laboratory or classroom setting. I teach EED 679 and I emphasize inquiry-based science teaching and learning with appropriate hands-on and manipulative activities.

In planning EED 679 coursework for Spring 2001, it is imperative to collaborate with science faculty, especially to those who have taught Bio 100 / 101 and to instructors who will be teaching the life and physical sciences to be able to connect, apply and reinforce science concepts and phenomena to the elementary school children's background and learning experiences.

The curriculum of LSITE Program was organized in such a way as to pair pedagogy courses with content (as with math and science) or to follow content courses (as with social science and language arts) when determined most appropriate by faculty in the disciplines.

Science Course Descriptions

Sophomore Year: Spring 2001

BIO 300: Nature Study (3) (Gen Ed). *Prerequisite: 1 course in college biology*

Intended for non-biology majors. Identification, structure, adaptation, life history, habitat, economic status, conservation of common plants and animals. Designed for elementary teachers. Two all-day field trips schedules on two separate weekends. Classwork, 2 units; lab and field work, 1unit.

BIO 318: Our Endangered Planet (3) (Gen Ed). *Prerequisite: 1 course in college biology*

Intended for non-bio majors. The effect of humans on the ecology of our environment. Species extinctions, the role of genetics, nature reserves, biology of small populations, and restoration ecology are discussed.

BIO 326: Disease (3) (Gen Ed). *Prerequisite: BIO 101 or equivalent*

Intended for non-bio majors. The origin and natural history of selected infectious and non-infectious human diseases including causal agents, mechanisms, and historical impacts.

BIO 330: Human Sexuality (3) (Gen Ed). *Prerequisite: 1 course in college biology*

Intended for B.A. in Gen Biology majors and non-majors. Development, structure, function, and dysfunction of reproductive and sexual systems in humans, physiology or sexual response, variations in sexual expression, law, birth control and abortion, etc.

BIO 333: The Genetic Revolution (3) (Gen Ed). *Prerequisite: 1 course in college biology*

Intended for non-majors. Principles of genetics and the meaning and impact of the new genetic technology in relation to society.

ASTR 115: Introduction to Astronomy (3) (Gen Ed). Designed for non-science majors. Survey of the universe. Stonehenge, solar system, galaxies, universe, search for extraterrestrial life. Opportunity for telescopic observation.

CHEM 101: Survey of Chemistry (3) (Gen Ed). A conceptual treatment of the basic principles of chemistry. Organic compounds including alcohol, ethers, esters, carbohydrates, fats, proteins, etc.

CHEM 105: Chemistry for Today's Living (3) (Gen Ed). Basic concepts of chemistry and how they relate to everyday experience.

GEOL 100: Introduction to Geology (3) (Gen Ed) Basic principles of geological interpretation; earth materials; origin and evolution of life; geologic time; evolution of landscape.

GEOL 102: Introduction to Oceanography (3) (Gen Ed) Basic principles of oceanography stressing the component of the dynamic ocean system.

GEOL 105: History of Life (3) (Gen Ed) The origin and early development of life, the evolution of life through geologic time, the extinction and replacement of organisms, and the future of life on earth.

GEOL 110: Physical Geology (4) (Gen Ed) Composition, structure, and evolution of the earth; investigation of the tectonic and hydrologic systems and their impact on development of landforms of the continents, etc. Classwork, 3 units; lab and fieldwork, 1 unit.

GEOL 272: Earthquakes and the San Andres Fault (3) (Gen Ed) Earthquakes as environmental hazards with special emphasis on the San Andres and other Bay Area faults

GEOL 350: Geology of the National Parks (3) (Gen Ed) Application of geologic principles to understanding and enjoyment of natural environments of North America focusing on geologic history and landscape evolution of the National parks.

METR 100: Introduction to Meteorology (3) (Gen Ed)

Fundamental causes and nature of weather and its elements, including winds, storms, precipitation, and clouds. Basic knowledge integrated in explanations of Bay Area weather and climate, interrelationships between human activity and weather, etc.

PHYS 101: Conceptual Physics (3) (Gen Ed). *Prerequisite: high school algebra and score of 550 above on the entry level math exam prior to enrollment.*

A one-semester course covering basic concepts of force, motion, heat, sound, light, electricity, magnetism. In preparation for PHYS 111 and 121.

Junior Year: Fall 2001

ASTR 350: History of Astronomy (3) (Gen Ed) Theories of cosmos from ancient times to the present. Estimates of size and age of the universe through the ages.

GEOL 302: The Violent Earth (3) (Gen Ed) The catastrophic geological agents that modify the environment. Significance of such processes as earthquakes and volcanic eruptions in the development of our planet.

METR 302: The Violent Atmosphere and Ocean (3) (Gen Ed) The atmosphere and ocean as agents of catastrophic change. Fluctuation in atmospheric and oceanic circulations and their environmental impacts. Implications of human modification of the ocean-atmosphere system.

Elementary Education Courses

ISED 150: Orientation to Education (3 units) - Teaching as a career; professional opportunities, qualifications and demands. Classroom visitation and field trips through educational institutions.

EED 646: Classroom Observation - Early Field Experience (1) - CR / NC grading only. Provides an opportunity to discuss observations: teaching strategies, working with students with limited English, content of the curriculum, and classroom organization.

ISED 160: Data Analysis In Education (3) (Gen Ed). *Prerequisite: a score of 550 or above on the Entry Level Math exam* Graphical representation of statistical data, introductory descriptive and inferential statistics including measures of central tendency and variability, standards scores, correlation and regression, probabilistic reasoning, random sampling, etc.

EED 678: Cultural and Linguistic Diversity in the Elementary Classroom (3) - A pre/corequisite foundation course for the Multiple Subject Credential focusing on critical cross-cultural understandings and teaching strategies.

EED 679: Curriculum & Instruction in Science (3) - Planning, developing, teaching, and evaluating learning experiences in science. Inquiry-based science activities appropriate for culturally and linguistically diverse elementary school children.

EED 684: Curriculum & Instruction in Mathematics (CLAD emphasis) (3) Methods and materials for teaching math to linguistically and culturally diverse elementary school students. Includes review of content of elementary school math curriculum, classroom organization, assessment and guided experiences in schools.

EED 749: Second Language Acquisition in the Elementary School (3) Examination of first and second language acquisition theories and their relationship to second language learning in the elementary school; psychological, social and linguistic aspects of second language acquisition/ learning of children; sociopolitical factors related to language issues in education.

EED 681: Curriculum in Elementary Social Studies (3) Curriculum planning and instructional processes; problems common to all curriculum areas with particular emphasis on social studies. Workshop activities including school experiences.

EED 783: Analyzing Child Behavior in a Culturally and Linguistically Diverse School Setting (3) - Theory and research-based examination of the cognitive, language, social-emotional-moral, and self-concept development of children in a multicultural/multilingual society, as they are affected by family, peer, culture, school and community.

EED 682: Teaching Reading/Language Arts (3) - Methods and materials in teaching reading/language arts to linguistically and culturally diverse elementary school children.

EED 782: Literacy Development in Elementary School (3) - Research and theory on literacy development in native and non-native languages at the elementary school level.

Post BA: Summer or Fall

EED 685: Student Teaching: Self-contained Classroom (3, 6 or 12)

EED 686: Student Teaching Seminar: Self-contained classroom (1-3)

The Integrated Bachelor of Arts in Liberal Studies and Multiple Subject Credential Program @ California State University San Marcos - KATHY NORMAN and ROBERT YAMASHITA

The Integrated Credential Program (ICP) at California State University San Marcos (CSUSM) is a joint-degree program from the College of Arts and Sciences (COAS) and the College of Education (COE). The ICP meets California State University and Commission on Teacher Credentialing requirements for a Bachelor of Arts in Liberal Studies and Multiple

Subjects teaching credential. The CSUSM ICP began in Spring 2000 and will graduate its first students in 2002.

ICP coursework is completed over six semesters. Each semester has a core set of required courses (varies from 9 to 13 units) that are taken as a block (3-5 hours of instruction over two afternoons per week). In addition to the core, there are recommended courses for each semester (3-6 units) and non-core COAS courses required for graduation.

Core coursework for each ICP semester is organized around a theme. Each theme matches one elementary public school curriculum area (multiculturalism, language & literacy, mathematics, science, social studies, and student teaching). A faculty team composed of COAS content specialists and COE methods/pedagogy specialists delivers the curriculum. The themed semester approach provides a number of advantages over the traditional programs (Liberal Studies Program and Multiple Subject Credential Program).

- Each semester has an identifiable set of objectives and expectations.
- ICP students learn *content* and *teaching methods* simultaneously.
- COAS faculty can presume that students are being trained for a particular profession and can develop specific content for them.
- COE faculty can presume that students have core content knowledge that does not have to be repeated.
- There is a basis to develop "shared" or "integrated" assignments to insure that students can connect content to pedagogy.

In addition, the modular design of the ICP offers the opportunity to strengthen other areas of the curriculum.

- The curriculum includes classroom field experiences in *every* semester. This includes an early student teaching experience (third semester).
- We can formulate a trajectory through which additional requirements for future teacher preparation can be infused throughout the curriculum – for example, adding curricular components for teaching with technology, service learning, and teaching special needs students.

The development of the ***Blended Science Semester*** in semester 4 demonstrates the strengths of the ICP. The blended science team includes three faculty members from the COAS and one science educator from the COE. The COAS faculty includes two professors from science content (chemistry and biology) and one social science professor (Liberal Studies). The primary goal is to better prepare future teachers by demonstrating the link between their science content courses and the future need to teach that content. In addition, the team wanted to address natural weaknesses in the upper division general education (UDGE) science requirement.[1] Achieving the goals required negotiating the one major structural constraint - the ICP could ***not*** require an additional UDGE science course (but it could add a social science course).

[1] The current UDGE science requirement consists of a single course in *either* science, math or computer science. The existing CSUSM Liberal Studies requirement requires a science course and adds an additional math or computer science course. In the traditional program, students may take any one of several courses for their required science course. They are not required to take Science and Society. Students take science methods during their year of the Credential Program.

The design of the core curriculum consists of 3 courses: science content, science methods, and science and society. In order to meet the specific needs of future multiple subject teachers, faculty in the Sciences created a new science course that is an overview of basic life science and physical science concepts. The science method course was synchronized with this course. The blending framework at this level clearly established the relevance of science content for future teachers. The Science and Society provides an important link to the content course and the pedagogy course. Its primary purpose is to provide students with an understanding of the social context of science, the nature of scientific practice, and the application of science in the world. It also provides important space where we can engage students in other critical aspects of science education, including an exploration of critical questions such as the difference between science and non-science, the logic and rationale behind the various "science standards," and the subtle complexities of science in action (and how they can facilitate teaching young children). The blending team developed several integrated assignments as mechanisms where the students' ability to integrate the three distinct educational moments could be assessed.

Course Descriptions

Science Education in the Elementary School: This course is designed to provide a comprehensive overview of the methods necessary to teach science to elementary school children. The course focuses on curriculum development, instructional strategies, and assessment in science. It includes independent and group activities to provide first-hand experiences.

Natural Science for Teachers: This course provides the prospective K-6 teacher with some background in the nature of scientific inquiry, data interpretation, and fundamental concepts in both Physical and Life Science. The course is based on an inquiry-oriented approach to learning the science content. The content is equally divided between Life Science and Physical Science.

Science and Society: The course provides prospective teachers with an understanding of the social context of science. Students will explore the social reality of science, scientific practices, the social consequences of science, and the development of science policy.

Appendix A

Summary and Comparison of Integrated Programs at Nine CSUs

Campus	Old Program Liberal Studies + Credential	New Program Integrated/Blended	Program Focus
CSU Dominguez Hills	Total: 12 units	Unspecified number of introductory courses taken at Community College 6 units upper division science Earth science & Science Methods (blended course - team taught) Total: 10 units 4 units inquiry/hands-on oriented	Junior and senior years
CSU Fullerton	9 units lower division science 6 units of upper division science Science Methods is part of 5th year credential program Total: 16 units	9 units of lower division science 3 units of upper division theme based integrated science course (SCED 410 Physical Science Concepts or SCED 453 Life Science Concepts) EDEL 430b Science Methods *taken concurrently with the integrated science courses* Total: 13 units 10 units inquiry/hands-on oriented	All 4 years
CSU Long Beach	BIOL200 (4) Biology & lab PHSC 122 (3) Physical Science & lab GEOL 102/104 (3/1)Geology & lab SCED 401Process	BIOL200 (4) Biology & lab PHSC 122 (3) Physical Science & lab CHEM 105 (1) Introduction to Chemistry (elementary teachers only) GEOL 102/104 (3/1)Geology	All 4 years

	Approach to Science (3) EDEL475 (3) Elementary Science Methods *taken in 5th year* Total: 17 units	& lab SCED 401 Process Approach to Science (3) EDEL475 (3) Elementary Science Methods *taken concurrently with SCED401* Total: 18 units 9 units inquiry oriented/ hands-on	
CSU Northridge	Physical Science for Elementary Teachers (4) Biology for Elementary Teachers (4) Earth Science for Elementary Teachers (4) Math/science methods for Elementary Teachers (3 -1.5 sci) Total: 13.5 units	Physical Science for Elementary Teachers (4) Biology for Elementary Teachers (4) Earth Science for Elementary Teachers (4) Ways of Knowing (3) Math, Science & Technology (3) Math/science methods for Elementary Teachers (4 - 2 sci) Total: 20 units	All 4 years
Cal Poly Pomona (quarter system)	Chemistry Biology Each science Physical science Methods (stand alone course) Total: 18 units	Chemistry & teaching Each science & teaching Physical science & teaching Biology *Pedagogy infused into three science courses along with early field experiences* Total: 16 units 8-12 units hands-on/inquiry oriented	All 4 years
CSU San Bernardino (quarter system)	5 units life science 9 units Physical & Earth Science Special Topics Courses Integrated Capstone (select from menu of courses)	5 units Topics in Biology Choose 1: biol, che, comp sci, geol Computer Technology for Educators Choose 2: chem or geol or phys in the classroom	All 4 years

	Total: 22 units	Elementary Science Methods *taken concurrently with a science content course* Integrated Capstone (select from menu) Total: 27 units 4 units hands-on/inquiry oriented	
San Diego State University	Biology Earth Science Physical Science Science Methods Total: 15 units	Biology Earth Science Physical Science Science Themes *newly developed course* Science Methods Total: 16 units 8-10 units hands-on/inquiry oriented	All 4 years
San Francisco State University		Total: 16 units _ 3 units hands-on/inquiry oriented	All 4 years
CSU San Marcos	Total: 12 units	Science Education in Elementary School (methods) Natural Science for Teachers (inquiry-oriented class evenly split between Life & Physical Sciences) Science & Society Total: 12 units 6 units hands-on/inquiry oriented	Junior & senior years

Technology: A Link to the Mountains and Beyond, Discourse Practices in a Web Course for Elementary Science Teachers

Kathleen S. Davis, University of Massachusetts, Amherst

Objectives

Despite recent science education reform efforts (AAAS, 1993; NRC, 1996), researchers continue to report the under-representation of females in science professions and coursework (NSF, 1996). As concerned educators, organizations, and institutions consider ways to facilitate females' legitimate participation in science, it is important to examine what serves as door-openers and gatekeepers to their science practice and how an inclusionary practice of science and science discourse can be developed.

Theoretical Framework

Introduction

Recent discussions about how persons join communities of practice--such as science--suggest that through engagement in social practice with experts and novices, individuals (a) acquire valuable resources, (b) learn the knowledge, skills, and ways of the community; and (c) interact and contribute within the profession and are seen as valued members (Delamont, 1989; Lave & Wenger, 1991). Full participation in a community of practice results not only in knowledge acquisition, but also in "*becoming* part of the community" and the development of an "increasing sense of identity as a master practitioner" (Lave & Wenger, 1991, p. 111). However, the structure and power relations within a community can open, limit, or close access to legitimate participation to individuals or groups (Lave & Wenger, 1991). If access to participation is blocked, then individuals can be excluded and/or marginalized.

Educational researchers have illuminated many factors that contribute to the construction of boundaries within the science community and the subsequent insider/participant status for some

groups and peripheral/outsider status for others including: 1) the exclusive curricula that ignore the approaches, contributions, and achievements of females, 2) the biased content of research agendas and the privileging of scientific approaches that are abstract, separate, and impersonal, and 3) hegemonic social and institutional structures and practices (AAUW, 1992; Harding, 1991)). Furthermore, issues of discourse and learner autonomy in inquiry, play an important role in females' legitimate participation in science activity.

Discourse

Becoming a legitimate participant in the science community entails the ability to explain and justify one's understandings, the questions that guide one's inquiries, the methods that one employs, and the conclusions that one draws (NRC, 1996). Key to legitimacy is the ability to talk science in accordance with beliefs, norms, and values unique to that practice. Yet, some aspects of traditionally accepted scientific discourse can be exclusive and limiting.

First of all, the competitive and aggressive nature of scientific discourse can marginalize or exclude some. In a study of women working in the sciences, they described the discourse of the science community as not about sharing ideas, knowledge, and skills and learning from that, but based in competition and aggression where individuals must continuously prove themselves and establish a superior and dominant position (Davis, 1996). For example, participants in this study reported that individuals in science contexts often made statements and posed questions, not for the purpose of sharing information or for finding out what someone else knows and learning from that, but instead, to posture—to let others know that only they know the answer or that the information that is shared is something that is important to his/her research and that it should be acknowledged. Informants described the discourse in science as aggressive--in their words: speaking authoritatively, arguing "like cats and dogs," "being criticized...[and] judged unfairly,"

humiliating..." "a constant... chopping away," "yelling at you," being "on the hot seat," and arguing to find "truth to the death." One participant described "the styles of the ways in which people relate information [as] a bit repugnant." The interactions in science settings were described as intense--where one needs to continually prove oneself.

To compound this, science values critical thinking and so students of science are asked to develop reasoning and critical response skills (NRC, 1996). They must be critical of theirs and others' thinking and be ready to hear such critique as well (AAAS, 1993). Science contexts such as these may be silencing for some as voicing one's speculations involves an element of risk. Speaking freely in classroom settings can be difficult especially when there is disagreement. The Benchmarks state, "Because youngsters want to be liked, this notion that one can disagree with friends and still be friends is not easy to accept (and may not be true in the short run)...(AAAS, 1993, p. 15). Also, due to their socialization, females may perceive criticizing others or being criticized as being disruptive and as challenging their relationships with others (Gilligan, 1991). Tannen (1998) notes that

> limiting critical response to critique means not doing the other kinds of critical thinking that could be helpful: looking for new insights, new perspectives, new ways of thinking, new knowledge. Critiquing relieves you of the responsibility of doing integrative thinking. It also has the advantage of making critics feel smart... but the disadvantage of making them less likely to learn from [others'] work. (pp. 273-274)

Interestingly enough, Davis (1996) noted that the kind of discourse that took place in the context of the all-female science setting she studied provided a contrast to the discourse the women described in their daily work and school environments. The nature of the talk within their group was based on the acquisition and sharing of information. Within the group, the members

would question others for information; share personal knowledge and experiences; make suggestions; tell stories; describe situations and events; give examples; advise; and report on activities and practices that individuals had tried out.

Research on discourse practices provides us with several ways to look at this issue. First of all, in her research, Tannen (1994) contends that individuals from different gender, ethnic, racial, geographic backgrounds engage in different conversational rituals. Based on her research of white, middle class men and women, she reports that, in general, men often use "banter, joking, teasing, and playful put-downs" and expend effort "to avoid the one-down position" (p. 23). Men consider questioning as a sign of being less capable. In general, men are more comfortable touting their successes. She notes that where work settings historically have had men in positions of power, such as science, an established male-style interaction is often the norm.

In contrast, women are more likely to ask questions when they are seeking information. They often seek "ways of maintaining equality, taking into account the effect of the exchange on the other person, and expending effort to downplay the speakers' authority so they can get the job down without flexing their muscles" (p. 23). Studies indicate that, among women, "discourse patterns reflect active listening, building on the utterances of others, collaboration rather than competition, flexible leadership rather than the strong dominance patterns found in all-male groups" (Thorne, Kramarae, & Henley, 1983, p. 18).

Importantly, as such discourse practices are reproduced within the science community, so is the oppressive, hierarchical structure that has long been in place in society and work settings such as science. In the same way that the sexual division of labor consistently shows a pattern of male dominance which thwarts any considerations that it occurs "naturally," the sexual division of labor in discourse is not a just a result of cultural difference but a reproduction of a male

hegemony in society (Uchida, 1998). The set of cultural rules that dictate how males and females should behave and talk are intricately intertwined with the positions in which men and women are placed in the hierarchies of society, including the science community. The strength of male domination demands a system of talk that "prioritizes...men's words over the words of women" (Lewis, 1993, p. 21), and such perceived status differences in science contexts can lead to silencing for women and other groups. As it is, males often dominate the talk and activity in science settings (Sadker, Sadker, & Klein, 1991).

Learner Autonomy in Inquiry

Hildebrand (1998) describes scientific discourse as positivist, masculine, hegemonic, and reflective of learning that is "received and reproductive" rather than "authentic and constructed" (p. 349). She points to the tacit assumption "that access to power in science will occur only if all students are taught to write as the scientific elite write" (p. 350). However, she contends that

> Only a limited access to power can be envisaged from this standpoint....[T]o uncritically perpetuate writing practices that are implicitly underpinned by an ideology that links science with power and masculinity is to choose to teach in ways that generate privilege for *some* students. (p. 351) (Italics in the original.)

As individuals see only the experiences, thoughts, and ideas of others as valued, then it may be difficult to confidently see a legitimate place for themselves within a community. In contrast, if individuals' meaningful inquiry, activity, and talk become part of the process of solving problems, answering questions, and determining practice, then they are more likely to develop an identity of legitimate participant.

Researchers working from feminist perspectives have proposed inclusive pedagogical approaches (Davis, 1999; Eisenhart & Finkel, 1999; Hildebrand, 1998; Rouchoudary, Tippins, &

Nichols, 1995) that provide students with opportunities to: 1) use and integrate the knowledge, skills, and tools of science and technology as part of relevant inquiry; 2) talk about their science activity in meaningful ways; and 3) engage in learning that provides multiple and diverse ways of talking and thinking. Previous research (Davis, 1996, 1999a, 1999b, Davis & Falba, under review) indicates that within multiple contexts, including the everyday school environment, students must be able to make decisions about their science based on their own insights and judgments; to ask meaningful questions and design their own explorations and methods of communication; implement goals, activities, and experiences; and reflect on the results of their investigations and the effectiveness of their choices. In this way, discourse comes in many forms--not only should it be considered as written and oral expression, but also as "having say" as equal participants within a community of practice.

This study examines the aspects of a science education web course that engaged female elementary teachers in science inquiry and talk. In particular, through this study, I explore 1) the characteristics of science discourse that support women's participation; 2) the instructional practices used to facilitate (or not) women's science activity and discourse; and 3) the ways the use of computer technology lead to the inclusion or exclusion of women's science participation.

Methods

The Course

The Science K-6: Investigating Classrooms Web Course was co-created by the author and a professor emeritus of the University of Massachusetts at Amherst and the WGBH Educational Foundation in Boston. The 14-week online course was designed for the professional development of teachers in science. Based on the Science K-6: Investigating Classrooms video series and funded by the National Science Foundation, the course aimed to foster meaningful discussions

about the nature and practice of elementary science education. As teachers engaged in the activities of this course, the instructors sought to provide the participants with a context for legitimate science activity and participation. With this in mind, the instructors of the course aimed to: (1) help teachers identify the elements of inquiry teaching and learning and implement them in their science classrooms, (2) introduce teachers to the nature of science by involving them in the scientific inquiry process, (3) explore with teachers the topics of constructivism, conceptual learning and meaning-making, equity, questioning, group work, student ideas, and assessment as they relate to learning in the inquiry-based science classroom, (4) encourage teachers to reflect on their own science teaching, the culture of their classroom, and the outside influences that affected their teaching, (5) guide teachers in carrying out a piece of original research about teaching and learning in their classrooms on a topic of their choice, (6) help teachers become familiar with the use of video, computers, and the internet as resources for professional development and as tools for improving teaching and learning, and (7) enable teachers to build a new notion of curriculum based on their construction of inquiry-based science teaching.

Throughout the semester, students looked at video clips of real-life classrooms investigating a variety of science topics and reflected on the teaching strategies they saw. Course readings spurred further conversations around topics such as questioning, group work, materials management, and classroom culture. In order to experience the inquiry process firsthand, the class collaborated on a simple investigation of rust. They also conducted their own individual classroom study addressing a topic of their choice. This study included making hypotheses, observing their own classrooms for evidence, analyzing data, and finally presenting their results to their peers.

Science K-6: Investigating Classrooms Web Course was structured as an online course with two scheduled face-to-face meetings. The first meeting was scheduled at the beginning of the course to ensure that participants were comfortable using the class web page and were informed of the course outline and expectations. The last meeting, held at the end of the semester, was to share the outcomes of their individual studies.

All other class sessions were held via the web. In these sessions, students logged on to their computers to post messages to online web boards. During the semester, students completed readings, watched videos of classroom practice created by WGBH in Boston, engaged in scientific and classroom inquiry projects, posted reflections about their investigations to the web site, and responded to the postings of other participants. The instructions for carrying out these interactions over the Internet were described in detail during the first meeting and subsequently on the course web site each week.

The Projects

Rusty Nails

During the first class, teachers were introduced to the rusty nail activity that would serve as a long-term inquiry project during the course. I opened the activity with a question about my 1990 Nissan Pickup truck. After recently moving to Massachusetts from Nevada, I came to find a hole, crusted with rust and about the size of a quarter, on the bed of my truck. I conveyed to the class my shock at finding this! Although my truck had been on the road since 1990 when I bought it in Illinois, I hadn't seen a sign of rust until that fall. As I showed them color overheads of the hole in question, I questioned the group: "What had cause this rusted hole?" "What is rust?" "What was the prognosis for my truck?" After some discussion of what they knew about

rust, the group was charged with making two nails, devoid of any protective covering, as rusty as possible. They were to design their own investigations to explore their questions around rust.

This project was designed to give the entire class a common experience in carrying out a scientific investigation. Using the phenomenon of a rusting nail, they made predictions, designed and redesigned experiments, made observations, and ultimately drew conclusions about their studies. They posted three Lab Reports on the web site about their observations, and they recorded information about their investigations in a Science Log.

Classroom Study Project

About a third of the way through the course, the teachers were asked to engage in another form of inquiry—classroom inquiry. In this project, teachers designed and implemented a study of their own classrooms to find out more about the factors that affected the way their classrooms worked and how their children learned. They had several weeks to design and carry out their studies, collect and record information in their Personal Journals, consult with an online study group, and finally present their results in a paper and lesson modification during the last class meeting.

Participants & Methods

Participants in this study included the three instructors and seven of the teachers enrolled in a 14-session, graduate-level science education web course.

Data was collected in the form of 1) pre- and post-instructional surveys, 2) interviews, 3) web postings, 4) journals, and 5) course documents. Pre- and post-surveys were used to investigate participants' beliefs and attitudes about science, teaching and learning, and previous skills and experience with computer use. Surveys provided demographic information, informants'

perceptions of what they experienced as a result of their course activities. Participants completed surveys at least twice--at the beginning and then at the end of the project.

In-depth interviews and semi-structured interviews were used. Interview protocols were developed to probe participants' conceptions of teaching and learning and their practices as teachers. Interview questions in this project focused on participants' beliefs and attitudes about students' learning and their teaching science, their experiences within the project, the significance and interest level in science activities, the benefits they received from the project, and the obstacles/limitations they encountered. All interviews were approximately 60 minutes in length, tape-recorded, and later transcribed. Pseudonyms were used throughout the analysis to maintain the individual privacy of the informants.

Documents include those associated with course such as syllabi and student work. Artifacts that described the beliefs and instructional practice of teachers included: lesson and unit plans, examples of student work, journals, and logs.

Data Analysis

Researchers used the National Science Education Standards to assess the professional development of teachers. Data was analyzed using the coding of qualitative data and domain, taxonomic, and componential analysis to determine critical patterns and themes (Spradley, 1979, 1980). Data sources were compared through the process of triangulation. The analysis includes particular description in form of direct quotes, general description in the form of taxonomies, charts, and diagrams, and interpretive commentary (Erickson, 1986).

Results

An intersection of several factors enabled the teachers in this course to legitimately participate in science activity and discourse. As in a previous study (Davis, 1999b), I came to

find that the use of computer technology (in this case, the Web) was not in and of itself the key factor in women's participation in science activity and talk. Instead, the use of computer technology in conjunction with a myriad of other factors came to bear in their engagement in science and its discourse. Key elements to their participation were: 1) engaging in the process of inquiry—"doing science," 2) having a say in their science process, 3) communicating with others about their science activity, in this case, via the Web, and 4) linking their own methods of inquiry with those of their students. The use of technology in this course, provided participants with new and more ways to access and engage in science activity and talk. However, there were some technological barriers to their science talk as well. I discuss these issues below.

Engaging in the process of inquiry—doing science

In their interviews, journals, and postings on the course web site, teachers in the course reflected upon their personal science learning in the class and the science learning of their students. They painted a picture of learning science through "doing," which included engagement in inquiry, reading scientific literature, and interacting with others.

Teachers' engagement in the inquiry project aided them in their use of the process skills of science as outlined in the National Science Education Standards (NRC, 1996). (See Table 1.)

Table 1.
Engagement in Inquiry

Inquiry Descriptor/ Participant	Michelle	Mary	Sheryl	Matt	Christine	Linda
Ask a question about objects, organisms, an events in the environment	X	X	X	X	X	X

Identify questions that can be answered through scientific investigations	X	X	X	X	X	X
Plan and conduct a simple investigation	X	X	X	X	X	X
Design and conduct a scientific investigation	X	X	X	X	X	X
Employ simple equipment and tools to gather data and extend the senses	X	X	X	X	X	X
Use appropriate tools and techniques to gather, analyze, and interpret data	X	X	X	X	X	X
Use technology and math to improve investigations and communications	X	X	X	X	X	X
Use data to construct a reasonable explanation	X	X	X	X	X	X
Communicate investigations	X	X	X	X	X	X
Communicate explanations	X	X	X	X	X	X
Think critically and logically to make the relationships between evidence and explanations	X	X	X	X	X	X
Recognize and analyze alternative explanations and predictions	X	X	X	X	X	X

For example, Michelle, a computer teacher and previous art major, documented her exploration of rust in her Science Log and in her Web postings. Illustrating the cover of her Log are words that describe the process of inquiry—Question, Experiment, Experiment, Question, Record, Analyze, and Explain. In her journal, she notes her initial thoughts and questions:

1) Salt... road salt "eats" cars, fine sand and salty moist air is why we are advised to hose our cars off after a trip to the seacoast. What is the role of salt? How does it participate in the rust process?

2) I think if I scratch up one the nails to expose more surfaces to the salt water, that will encourage faster rusting. What am I going to scratch that small surface with? Another nail? A wire brush?

3) Why am I thinking about this "expose more surfaces of the nail?" What do I think rust is and why do I think smaller or thinner pieces of metal will get rustier, or rust faster than a denser piece of metal?

4) Why do I think that these nails are made of the same metal that cars are made of? What kind of metals are nails made of? And cars?

5) If salt water will rust metal faster than fresh water, why are ships and boats that are made of metal allowed on the oceans?

Michelle then designed her investigation. Below, excerpts from her Science Log document her process. In bold type, she noted her reflections about her observations and her hypotheses.

Lab 1 Rust Is A Sign of Neglect

When Dick told us that our nails had "been treated with a substance to remove any oils from their surface", a couple of us immediately dropped said nails. (I heard their pleasant clinking on other desks than my own.) **1. Nails are not protected from the producers of rust.**

I put each nail in its own (expendable) saucer. One on the kitchen counter, one on the porch. Each nail sat in a puddle of water. In a few hours (If I knew rust happened so fast I would have measured the time then!) [the] inside nail was "bleeding rust", outside nail was encased in ice, not

rusty. **2. Cold preserves nail. Warmth encourages evaporation, which seems to promote rust.**

2.A. Have to re-do [the] experiment for time measure.

...Outside nail is slightly rusted, but took longer because snow and ice preserved nail. Inside nail needs more water added constantly. It is very cruddy, flaky, big rust. The rust on outside nail is fine textured, not nearly as extensive.

3. Rust can be a sign of careful, deliberate care to cause rust. I want to think about "why salt" before I do salt. Also need more nails.

Lab 2 Only one Variable, and :^(only one nail :^(

When I get more nails (when I paint my masterpiece) I will start with more variables.

Meantime, my experiment was limited to observations on the effect of temperature. On one of the web sites, I read that "heating of the iron can induce rust." I began pouring a bit of boiling water over the "inside" nail (which is in a saucer) each time I made a cup of tea, or instant coffee, about 3 times a day.

The problem is not having any way to measure, to explain how rusty the nails are or are not. This only: When cold tap water was used, the rust process was slower. (How slow?) The rust was finer. (How fine?) NOW: After the boiling water treatment, the rust is flakier. (How much flakier?) I BELIEVE the nail looks skinnier. (A caliper, do I need a caliper?)

Last snowstorm, my "outside nail" disappeared. Everyone here denies having anything to do with the disappearance. Could the wind have actually blown a saucer off the porch?

Lab 3 Why not Salt? Why not Pepper?

By Michelle

In my own nail investigations, I focussed on temperature. I decided that the second lab report and my second experiment did not have particular enough controls to help verify the effect of variables.

Experiment #3

Controls: 3 new nails

3 white china bowls

sodium free spring water(Indian Rock)

Variables: 1/2 cup room temp. water

1/2 cup boiling water

1/2 cup water with 6 ice cubes added

Hypothesis: because I read that "heating iron will cause it to rust quicker", and my first experiment showed that the nail in the warm environment rusted sooner and further than the nail in the cold environment, I predict that of the three temperatures, the nail in the boiling water will rust sooner and further than the other two. I further predict that the nail in the bowl with ice cubes will be the last to rust.

Observations: The first nail to show signs of rust was the nail in room temperature water. The last nail to begin rusting was the nail with ice cubes.

Conclusion: This brings up questions. Were the nails really identical? I didn't wipe them off with vinegar or lemon juice, just took them out of the box and put them immediately in a container to avoid contact with my skin oil and moisture.

Did the increased volume of water caused by ice cubes skew my experiment, and reflect volume of water as a variable rather than temperature?

Does very hot water impede rather than induce oxidation of the nail?

Is the process of boiling an oxidation-reduction reaction? Is steam oxidized water?

I boiled the water in a stainless steel pan, because the inside of the enamel teapot has rust stains in it. I happened to let the bottom of the pan get scorched after I measured out 1/2 cup of water into the bowl. The scorch mark is the same color as rust. Is it rust?

Any way, judging by my three lab reports concerning temperature and rust, it seems constant that very cold does not induce rust.

Jumping to Conclusions: David, being intrigued by the heat question, and what I learned from the Internet (a valid source?), we assumed that it would have to be real hard heat that would turn the nail red, like in a kiln or burner flame May be this simple experiment of mine says that boiling hot is hot enough, or even a degree or so cooler will do.

New Design: requires more mat'ls. Bunsen Burner, thermometers (to be exact about temperatures) more bowls, more nails, and I would like some way to keep temperatures constant. One nail encased in ice, and watch it to see if it rusts ever so slowly (in experiment #1 the outside nail was always cold, but fluctuating degrees of cold.) The red hot nail could not be kept at a constant temp for long, and when plunged in any water would cause steam, like a blacksmith does (how did folks invent that process...hmmm)

The overall topic of study for the project was predetermined by the instructors; however, teachers had a great deal of say and ownership within the project as they decided the questions to explore, the design for their experiments, what was important to observe, what data to collect and how to go about it, how to resolve problems, and how to redesign. (See Table 2.) Teachers interpreted their data and constructed their own understandings based on the results of their investigations.

Table 2.

Student Autonomy

Participant/ Project Descriptor	Michelle	Mary	Sheryl	Matt	Christine	Linda
Students' interests are acknowledged & addressed	X	X	X	X	X	X
Students' skills are acknowledged & addressed	X	X	X	X	X	X
Students' questions are built upon	X	X	X	X	X	X
Students' ideas are built upon	X	X	X	X	X	X
Students set goals	X	X	X	X	X	X
Students plan activities	X	X	X	X	X	X
Students design the environment	X	X	X	X	X	X
Students assess work	X	X	X	X	X	X
Students explain and justify their work to themselves and others	X	X	X	X	X	X

Communication

The use of technology in the project fostered communication in many ways. Teachers: (a) interacted with others about their inquiry, (b) critiqued their investigative process and recognized and analyzed alternative explanations and predictions, and (c) collected data from outside resources. In addition, the structure of the course provided the students with more space for talk than the traditional classroom context and, for some, a more comfortable space.

Interaction about Inquiry

While interacting with others about their inquiry via the website, teachers were able to communicate ideas, feelings, and experiences regarding their investigations and provide others with alternative ideas, critique, suggestions, questions, and encouragement. (See Table 3.)

Table 3.
Benefits of Communication

Participants/ Kinds of Communication with Others	Michelle	Mary	Sheryl	Matt	Christine	Linda
Share ideas	X	X	X	X	X	X
Share feelings	X	X				
Share experiences	X	X	X	X	X	X
Provide others with alternative idea	X	X			X	
Acknowledges others difficulties as their own	X	X			X	
Asks questions	X	X			X	
Provide others with critique					X	
Provide others with suggestions		X			X	
Provide others with encouragement	X	X		X	X	
Expressed appreciation for comments of others	X	X		X	X	

Christine commented:

> The actual back and forth was useful getting people's comments -that was interesting....There was a diversity of experience and background among the students. Some were perhaps asking more sophisticated questions and others, but they were all kind of actually kind of interesting questions, interacting back and forth on them you make connections between them....They would bring up questions you might not had thought of - that was useful, helpful....By encouraging everybody to comment on everyone else's questions and statements encouraged people to really

look at other people's way of looking at things and that doesn't happen often among peers and which you wouldn't have necessarily done if [you] were in a regular class.

Mary stated:

I found myself asking questions of everybody. "Where should I put - how should I put it - can you give me a really good idea" because I want to tap into the best ideas of everybody.... I think it was open-ended kind of questions that we had in the web course - getting onto the web and reading through some of the stuff that other people wrote... I felt more grounded because some their stuff wasn't working, or they had questions and I said "Oh thank God", so now I can do something silly like that too and not feel bad. So I would say it was the inquiry part of that piece of it that was really important.

Michelle noted:

I think everyone ran into problems with the course; the encouragement made such a big difference. You don't necessarily find that in every course that you take, and the atmosphere that was created was one of cooperation more than competition, I think. I think I felt that really strong.

Michelle's investigation experiences provided a good example of the interactive discourse that took place among the teachers in the course. In her second lab report, Michelle publicly described her struggle to quantify the rusting of her nails she had placed under different conditions.

Lab 2 Only one Variable, and :^(only one nail :^(

....The problem is not having any way to measure, to explain how rusty the nails are or are not. This only: When cold tap water was used, the rust process was

slower. (How slow?) The rust was finer. (How fine?) NOW: After the boiling water treatment, the rust is flakier. (How much flakier?) I BELIEVE the nail looks skinnier. (A caliper, do I need a caliper?)

In her journal, she noted how, missing this element to her investigation, she found it scientifically wanting. In her journal she stated:

> All the teachers are designing their own experiments and doing them, and commenting on each other's variables, and controls, observations, conclusions, and questions. These are mine, so far. They are not what I would call the most scientific. I believe that some of the other teachers' experiments are more scientific than mine. Why? Because I didn't measure measurable things, like how much time, how much water, the exact temperature.

Course participants and instructors responded to Michelle's queries about a way to measure the quantities of rust on her nails with encouragement and several suggestions. Below are their comments.

Comments on "Only one Variable, and :^(only one nail :^(":

Only one...only one! Mary

- at 12:17pm Mar 28, 1999 EST

(With apologies to Bill Cosby for stealing that line from his Noah routine!) I couldn't help a chuckle over the mystery of the missing nail. Any wildlife which could have stolen it? I, too, am looking for a way to quantify the degree of corrosion; a fine scale before and after? scraping off the rust and weighing that? I am open to ideas. I am currently estimating it crudely by the depth of the sediment on the bottom of the jars, but that is pretty rough. Perhaps the effect of temperature is marginal? I, too, have trouble trusting my experimental

technique and design. I keep thinking of things I forgot to control...(sort of like my life, these days...!).

Measuring Rust () Carrie

- at 02:28pm Mar 28, 1999 EST

You say you have a problem, not being able to measure or describe how rusty a nail is... Is this a good next idea to focus on as you plan your further rusty nail investigations? Could you create a descriptive scale upon which you could rate your nails? An interesting idea!

reply to Michelle () David

- at 04:43pm Mar 29, 1999 EST

Carrie's suggestion is a good one. How can we set up a scale of "rustiness." In the meantime, I am fascinated by your question about heat deterring rust when a nail is treated by heat. I'll bet a dollar to a doughnut that they mean real hard heat. Like a flame from a burner. A minute or so of treatment or letting it get red hot could be a good bet since that would probably "harden" the metal like they do at a blacksmith's shop. Interesting. I'll be interested in what you decide. I'll look for an experimental design soon.

to Mary, Carrie, David () Michelle

- at 11:05am Mar 31, 1999 EST

Thank you for your comments! It occurred to me the other day that weighing the nail would be a measure, better perhaps than a caliper. I like Christine's idea of measuring the rust scrapings. I agree with you all that some kind of design has to be made to depict and communicate, to let us rusters know, as well as convey our beliefs to each other.

I think I may be getting behind, because I am not online at home, and my times for being on

this site, and posting, are limited. Further limited by error messages from the computer (whose server is down?). But I will continue to post when I can. Sometimes I get a whole posting typed and it won't go through, sometimes access to the next page is restricted, and the message says "document done".

Rust ruminations () Mary

- at 12:17pm Mar 31, 1999 EST

Re: rust weight, I don't know where to find a scale with fine enough measurement capability, though maybe they have one at the HS. It was just a thought born of frustration. Good luck with your computer woes!

In her Science Log, Michelle recorded how she followed through on several of the suggestions provided, and some new ideas of her own, to record her observations and measure the amount and kinds of rust on her nails. She drew pictures with the aid of computer graphics. She took photos, but found them misleading. She devised another system where she took the nails out of their saucers and put them on the kitchen counter at a distance from each other. Pieces of rust fell off each nail. Scotch tape was used to pick up the rust from each nail and placed on white paper. She suggested "a possibility for measurement."

Could there be a tool (wire cutters?) which would cut through nail fairly easily without squishing the metal? So that we could look at a cross section and see how much nail is affected by rust. Maybe our sight could be helped by a magnifying glass.

She also devised a "verbal scale for rustiness" or defined various types/stages of rust.

What was fascinating about this process of student reporting and interaction, was the students' ability to question and self-critique their investigative process. This was a component

of each participant's inquiry process whether it involved reassessing preconceived ideas, acknowledging the need for more study, or rethinking their investigative design. (See Table 4.) The interaction between students appeared to facilitate their inquiry process.

Table 4.
Kinds of Critiques

Participants/ Kinds of Critiques	Michelle	Mary	Sheryl	Matt	Christine	Linda
Preconceived ideas	X	X	N/A		X	X
Need for more study	X	X	N/A	X	X	X
Methods of investigation	X	X	N/A	X	X	
Need to control for variables	X	X	N/A	X	X	
How to/need to quantify/measure	X	X	N/A		X	
Outside factors influencing results	X		N/A	X	X	
Results when compared with the results of others	X	X	N/A	X	X	

Collecting Data from Outside Resources

The design of the course encouraged students to look to outside resources for more information to help them with their investigation of rust. During Session 3, students were asked to "surf the Web for information that might help you in your new experiments" and, during session 4, "conduct a web search to collect information about your science investigation. Add web sites to the class Library by posting briefly annotated choices of good sites to the Library under New Web Sites."

Michelle began her quest to find out more about rust as she designed her first experiment. She went to the web and "asked Jeeves" (www.askjeeves.com): "What kind of metal are cars made of?"

Sheryl found that her use of the Internet has opened up a new way of learning and communicating for her and her students.

> There [are] a lot of different web sites that [can] be…accessed… and, without the Internet, those channels for information [aren't] open. I have a lot of bookmarks on my computer, right now, that are through WGBH and some that I gathered from that class. All I can say is that when I first started teaching. I used a textbook and that was it. I mean I showed movies, supplemental activities, and lab, but the text was very important. I think now what I'm doing…I'm having the Internet and the web sites that are available as a source of information a lot more than any textbook.

A Big, Safe Space to Speak

Course participants related that, although initially they may have had some uneasiness posting their ideas for everyone else to see, they felt that the format of the course provided a safe place to share. Michelle pointed out:

> It [the course] was a little bit scary then it was fun…sometimes I'm very critical my own writings….Posting responses…and not be in a person to person setting--sometimes I would go to the library online and see, I think it was Mary, she was always first - and always thorough. I would be like "errrrrr!" But what was good about it was that I thought she was very bold. I think what I'm trying to say is that I was scared and hesitant to post something not knowing how it was going to look. "Is this what they're looking for?"

Some people, myself included, will inevitably sound better on paper after I have chance to edit, think it through. When I think off the top of my head, I will maybe get so many ideas at once that I either stop communicating or I digress and try to jump back and can be hard to follow. So this way would be easier for me in terms of... style of communicating.

Mary pointed out:

> You know it was motivating to go and see - I wanted to see if anybody answered my thoughts, you know, like when I posted a message. I always went to see if anybody answered. Maybe now that I'm not so afraid of science, I might enjoy an adult science course, but I really don't know. I don't think I would ever sign up for one for fear that I would be the least knowledgeable person in class. Over the Internet, it was more comforting to know that I was just out there in Cyberspace, and nobody really knew me, and I could type in anything. "Do you remember her?" - "No." (laughter) That kind of thing. The anonymity was comforting. (laughter) I could ask a silly question, or I could ask whatever and write it... and no one was going to say, or I wouldn't have to see their faces in disbelief that [I] asked this question. And people wrote nice [things] back, "Oh, I know what you mean." That was a nice part of it.

The format of the course also allowed more space to talk. There was no opportunity for interruptions from instructors and other students; there was not the responsibility to "share air time" with others. There was no limit to how much one could report about whatever. Michelle pointed out:

> When you post your responses - it's different than sitting in a classroom setting where not everyone might get a chance to speak.... Some people in a group discussion want to talk to all the time, not that they don't want anyone else to talk. So you have that kind of group dynamics that the design set-up eliminated that which can be problem for all teachers and learners.

When the participant interaction is mapped out for the three Lab postings, there is a notable amount of student-to-student interaction. Course participants were only required to respond to one other student. However, conversation maps show that there was a great deal more interaction that took place.

Christine described how different this was from a traditional course:

> Frequently, you might interact with people you know in the class but you don't have to interact with everyone in a class...unless you're in a small seminar type.... It's usually...more the teacher has set-up the issues you're going to discuss....[There was] certainly more [peer communication] than a lecture course - even more than a lab.

<u>Constraints to Communication</u>

Many participants experienced constraints when it came to communicating with their peers during the course. Concomitant with the amount of time required for the reading of comments and the posting of responses, not everyone could readily get on-line: the lines were busy; the server was down; they did not have a modem at home or a computer; they used a computer at school or a local library and it was not always available. Also there were technological snafus that often appeared and interrupted students' ability to post messages and their work for the class. Michelle's posting highlights several of these problems.

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Michelle explains her problems in detail:

I was not on-line at home, and so I reasoned that I could work on the course during my lunch break at school and otherwise at my library, which is on-line. And there were a variety of things which tended to impede any work getting done. We have changed Internet service providers at the school, and I had a terrible time with that, because some of the times we couldn't get on-line. I couldn't bring up the Web site for the course. And at the library, you have to sign up for time. It's a very popular activity at the library, to go on-line--all ages of people do it. It felt like everybody... wants to use the library computers to go on-line. And then, so, therefore, I would have to wait. You're limited to one hour [at a] time. One day... I spent three hours on the course. And I figured this to be an average per visit, because I would read the comments that my colleagues had written, respond to their comments, and then also read my assignments and... post whatever work I could. And it was all really enjoyable, but it was time-consuming and got frustrating when there was somebody behind me in line and I only had an hour, and I still was having some problems getting on-line, getting to that Web site at school.... Then, eventually, I found that I

had to get on-line myself, and I took advantage of AOL's offer for, I think, one month free, and that was much more pleasant, working at home on the course.

Getting on-line and staying on line was an issue. Christine reported, "I occasionally got in trouble when I got kicked off the Web, and then I had to get back on because I'm on a remote access and occasionally my thing would hang up and I would have to finish typing and put it back on again."

There were also complexities participants experienced as they tried to negotiate the web site. Christine pointed out, "The main problem I had was [that] the site was very complicated. I had to check about 15 different places to find everything. So that was a bit cumbersome in terms of design of the web page."

Despite these constraints and though the course required students to spend a lot of time with assignments, reading responses, and postings, several viewed the web as a good means to communicate that also eliminated travel to a course site which also served as a constraint to their pursuing professional development activities.

One limitation of the web site was the fact that course participants could not provide either photos or drawings to illustrate their observations. Several of the teachers' Science Logs contained either drawings made by hand or by computer as well as photographs. Students' communication might have improved if they had been able to add this dimension to their communications with each other.

Making the Link to the Classroom

Interesting to this context is how the teachers' own experience with inquiry acknowledged and influenced them to provide students with autonomy in their science learning. As a group, the

course participants saw that as they were given a great deal of autonomy in their science activity (See Table 2.), it was important to "[Let] the children have the reigns more."

Mary thought that the student design aspect of the web course was the most challenging and yet it helped her see the openness of science and how she could be more open-ended in her teaching. She said:

> I felt comfortable…just knowing to come in and say, okay, this is the question. What are all the different ways we can look at the question. Feeling like there were no tidy boxes or correct answers. The most important thing was the inquiry - to get kids interested and stimulated thinking. Where it went from there okay….I think I'm much more open ended. I was always open-ended - it's kind of my personality but I think I'm much more open-ended now.

Michelle shared:

> I liked the project we had. I liked how different students approached it differently that was no right way, no wrong way. Some maybe could be called more scientific than others, but we were all being scientific. The experiment was always to [decide] what materials to use and to think about "Why?" To be given this idea, this project and then to have my mind open to the questions--so many more questions came -- learning to love the questions. It was just - I keep using the words fun and entertaining but it was an enlivening experience because it made me feel happy to be alive. This is too funny. I'm thinking about rust. I'm noticing rust everywhere and I now…[and] have my 5th graders…think about rust, to notice rust everywhere. Who would have thought there would be so much concern about rust?

Michelle, a computer teacher, described how the students in her computer class engaged in the rusty nail activity with her.

> The fifth graders… rusted nails, yes, because I'm not, per se, a science teacher…. Seeing them only once a week, it was a perfect project when I was rusting my own nails at the same time. What does this have to do with computers? What do we do with the computer?….[W]e had access to the Internet, some research. We did searches on rust, and we came up with new vocabulary words to learn such as galvanized and learned that there were businesses that were very actively interested in preventing rust. We also used the computer for word-processing to make a list [of] where the children had observed rust through the weekend – that was their homework. Then on Monday, we typed it up.

"Things seem rather out of my control," Michelle wrote in her journal, "but the children are thinking and planning." She explained their process:

> At the very, very end…the fifth grade had… made up their own experiments – what they wanted to do was to see what substance would rust nails faster or retard rust and so on….Experiment #3, they don't want to hear about variables. I partake in experimenting with them, explaining why I am using two bowls, one with salt and one w/out salt. Someone adds a galvanized nail to each of my bowls. And a threaded nail for good measure. The threaded nail was first to rust, as we predicted, and it happened to be in the salted bowl. No threaded nail was in the unsalted bowl to be a control. The galvanized never rusted--yet. Although we had talked about galvanization, and I showed info on a web site about it, one student was intrigued by these nails and asked," Why didn't those get rusty?"

"Those are the galvanized nails."

"What does that mean?"

Now she's engaged in inquiry.

One girl suggests that we do a bowl with pepper, too. I begin discussing why not pepper, and realize there's no reason why not. Meantime, being put into the bowls are all materials at hand: chalk, ink, cardboard. I ask each team what their theories are. The experiment has changed. It is truly their own. They also decided on their own to use a variety of nails.

One child showed me that he was going to rust a nail quicker by coating it with Vaseline. "What will the Vaseline do?" I asked. "Add moisture and keep the moisture in so more rust will happen." The next week he was SO EXCITED. "I made a discovery!" he crowed. "Vaseline prevents rust!!!!!"

[T]he bowls, which were white Styrofoam, had all different colors in them and there were all different stages of rusty nails. I kind of wanted the younger kids to see them because it was fascinating and probably also because maybe I'm a crazy lady, I don't know – as an artist as well the whole thing looked like art to me as well as science. It was sort of like a still life with "rusty nails" pictures. It was beautiful!!!....The younger children were very intrigued by it and they had a lot of questions....They said, "Are you still going to be teaching computers when I'm in fifth grade?" "This is what you do in fifth grade." It was a very exciting time.

Michelle indicated that, as a result of her experience, she "will be less rigid...about maybe naming things and have more activities oriented. Instead of dealing with vocabulary first, the

vocabulary will come last. Instead of telling students what they will find, asking them what they found.

> And you know that approach was almost too unusual for some of my students as well as my own children....My children and I were getting [in] those strollers and were out by the reservoir when we saw streams - and it was rusty streams. Every little rock and pebble was covered with rust. My older daughter asked, "Why is that stream all brown and rusty?" Instead of saying, "Well, it's ferrous oxide....", I said, "Why do you think?" and that's not what she's use to.
>
> Also [a] student that I have...brought in a science book and said, "Here's a real experiment we can do - which goes like a recipe - just get this all together this way and you'll come out this." That seemed to suit her better than "here's some material and go do an experiment" kind of attitude. So I think we always knew this: there are some people who want to have it very structured and you encourage them to take the reigns a little more themselves. There are others who can go and run with it.

At the beginning of the course and then, again, at the end of the semester, the teachers were asked to capture their beliefs about teaching and learning in a metaphor. Their metaphors changed over that time indicating a change in role as teacher, generally from that of a director to more of a facilitator. Christine stated in her final paper:

> In February, I set out two possible metaphors...teacher as a guide in a vast, exotic bazaar, and the teacher as a quilt maker....When I described the bazaar, I was primarily concerned with a variety of experiences, a choice of many interests or directions....I saw myself as a mapmaker, helping students to filter and organize their experiences....I see my role as a more active leader now, helping students to

explore, but bringing them back to... write their travelogue—to describe and make meaning from what they have seen and to communicate that meaning to others. I need to ask questions, encourage them to ask and reflect about what they are seeing. The quilt maker... I would see myself as helping to provide a stout backing on which students can fit their designs....students need to be encouraged to plan out their designs....I need to help them display the whole... and to make connections with other learning.

Mary moved from Master Chef to Head Nutritionist. She indicated that her role was to "monitor the concepts that the children are forming, directing, and clarifying their meaning-making." Now "they are the chefs who are creating for themselves scientific meaning."

Michelle revised her view of herself as Rumplestiltskin and Mary Poppins "where I was the action, the center of attention....Remember the old tale by Marcia Brown about the peasants who seemed to have nothing to eat, nothing to share with the wanderer who... told them they could make soup from a stone?" In her new metaphor, Michelle is the stone. "Not quite as inactive as the stone," she said," but I am at the bottom of the cooking kettle. I have always been with them, the student community. Eventually they will find out they can "make soup" without me. The great importance of the stone was that it made the people curious and willing to get involved."

Conclusion

In sum, the scientific activities and means of communication embedded in the web course, outlined in this paper, provide a good model for an inclusive pedagogy for females. Meaningful and autonomous activity in scientific inquiry was key to the legitimate participation in science of the women enrolled in the course. They had much say in the questions that were asked, the

designs of their investigations, the critique of their exploratory process and thinking, and communication of what they observed, thought, and questioned. This provided them with a science that was "authentic and constructed" instead of "received and reproductive" (Hildebrand, 1998, p. 349) and a meaningful context for discourse.

Though scientific discourse is often blanketed in competition and aggression, this setting was rich in science talk and cooperative and constructive. The web context and the design of the course provided an inviting setting for participants to share their inquiry process, read the science doings of others, reflect upon their own explorations and those of their peers, and provide support, ideas, and suggestions. Though non-competitive and non-aggressive critique is often difficult to establish in classroom settings (AAAS, 1993; Lampert, 1990), the web course appeared to provide such an element in the learning process. In fact, the talk of the course participants greatly mirrored the talk of the Women in Science (WIS) group described in this author's previous research (Davis, 1996). Indeed, as described earlier in this paper, the discourse of the WIS group was based on acquiring and sharing information. Within the group, the members would question others for information; share personal knowledge and experiences; make suggestions; tell stories; describe situations and events; give examples; advise; and report on activities and practices that individuals had tried out. In both the WIS group and the web course, participants found the setting to be supportive and critical to their learning process.

Finally, the use of computer technology in this context, was a great enabler of participant interaction and science talk. Compared to the traditional classroom setting, there was more space for individuals to explain what they were about in their explorations and more opportunity for peers to view others perceptions, experimental designs, and findings. The web context allowed for more opportunities for dialogue between participants than one would find within the confines

of even a 2 1/2-hour graduate course. Though missing the possible social advantages of face-to-face interactions, the web course design provided a discourse-rich setting.

In sum, this researcher is finding autonomous scientific inquiry is a critical element of an inclusive pedagogy. Such activity provides learners with meaningful activity about which they can talk. Computer technology continues to offer learners with many venues to communicate their understandings, activity, and questions. For females' legitimate participation in science and science talk, these approaches must be considered.

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THE IMPACT OF CONSTRUCTIVIST INSTRUCTIONAL METHODS ON PRESERVICE TEACHERS' ATTITUDES TOWARD TEACHING AND LEARNING SCIENCE

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This paper documents a three-year longitudinal study designed to track changes in preservice teachers' attitudes toward teaching and learning mathematics and science while enrolled in an Urban Preservice Degree Articulation in Teacher Education (UPDATE) Project. This project was funded for three years jointly by the US Department of Education Fund to Improve Postsecondary Education (FIPSE) and the Massachusetts Eisenhower Higher Education Development Program. The primary goal of this project was to provide a pathway for urban paraeducators of color to become certified teachers. This pilot project was designed to address the need for more teachers that reflect the ethnicities of the student population in urban public school districts.

During the first year of the project, preservice teachers – all of whom were paraeducators - were exposed to mathematics content using constructivist instructional approaches: collaborative group work; problem solving; the use of manipulatives; and calculators. Three mathematics courses were redesigned as part of the UPDATE Project and offered during Summer and Fall 1998, at Springfield Technical Community College. Previous research documents that these reformed mathematics courses had a positive impact on the preservice teachers' attitudes toward mathematics (Gibson, Brewer, Magnier, McDonald & Van Strat, 1999). In Summer 1999, preservice teachers enrolled in an introductory Biology course where content was delivered through traditional pedagogy consisting of lectures and note taking. This

Biology course resulted in a negative impact on preservice teachers' interest in teaching science (Gibson, & Van Strat, 2000). The following year, Summer 2000, preservice teachers enrolled in a redesigned introductory Physical Science course taught using constructivist instructional methods. The focus of this paper is to present changes in: preservice teachers' attitudes towards mathematics and science; preservice teachers' critical thinking skills; and preservice teachers' conceptual understanding of physical science.

Mathematics and science reform movements endorse inquiry-based instruction grounded in constructivist pedagogy. The National Council of Teachers of Mathematics (NCTM, 1989; 1991; 1995), the Mathematical Association of America [MAA] (Tucker & Leitzel; 1995), the National Research Council (NRC, 1996; 2000), the National Science Foundation (NSF, 1996), and the American Association for the Advancement of Science (AAAS, 1993) advocate using a constructivist method of teaching, in which learners construct knowledge through inquiry.

> Scientific Inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientist study the natural world. (National Science Education Standards, 1996, p. 23.)

The research literature on teacher education indicates that teachers tend to teach the way they were taught when they were students (Brown & Borko, 1992; Kennedy, 1991; NRC, 1996). Typically, future teachers spend untold hours in college classrooms with instructors who model traditional pedagogy. Consequently, they develop beliefs about teaching based on their in-class experiences. This places specific emphasis on the importance of redesigning mathematics and science courses at the college level. If we expect K-12 teachers to change the way mathematics

and science are taught college faculty must model inquiry-based, student centered pedagogy (NRC, 1997).

Research studies comparing the difference between traditional and constructivist teaching methods using different groups of secondary school students abound in the literature. In most of these studies, a control group of students is exposed to traditional methods of science instruction, while the experimental group of students is exposed to constructivist methods of science instruction (Chang, Chun-Yen & Mao, Song-Ling, 1998; Ertepinar & Geban, 1996; Geban, Askar & Ozkan, 1992; Gibson, 1998; Jaus, 1977; Mattheis & Nakayama, 1988; Padilla, Okey & Garrand, 1984; Purser & Renner, 1983; Saunders & Shepardson, 1987; Scheider & Renner, 1980; Selim & Shrigley, 1983; Shrigley, 1990; Wollman & Lawson, 1978). These studies conclude that inquiry-based science activities have positive effects on students' science achievement, attitudes toward science and school, cognitive development, laboratory skills, science process skills and understanding of science knowledge as a whole when compared to students taught using a traditional approach.

Much research has focused on comparing the two methods of instruction. However, one limitation to these studies' experimental design is the failure to study the impact of pedagogy on the same group of students over time. Research that looks at the impact of the two different types of instruction on the same group of students has rarely, if ever, been conducted. In this study we documented the experiences of preservice teachers who were exposed to both types of instructional methods (constructivist and traditional approaches; reformed and non-reformed courses) and have tried to understand how instructional methods impacted preservice teachers' attitudes toward teaching and learning mathematics and science.

Background

Project UPDATE is a collaboration between Springfield Technical Community College (STCC), the University of Massachusetts-Amherst School of Education, the University of Massachusetts (UMass)/University Without Walls (UWW) and the Springfield Public Schools. The project was designed to address key issues, for teachers and students in urban school districts, involving equity and multiculturalism. Specifically, urban districts have a disproportionately low number of teachers of color with respect to the student population. Further, urban districts are in need of teachers who combine sensitivity to issues of diversity with technological competency. Additionally, urban districts are in need of teachers capable of bridging the social gap between themselves and their students to assist children from many ethnic backgrounds to cope with the complex social issues facing them (Weiner, 1993). Preliminary outreach efforts revealed that many paraeducators in the Springfield Public Schools were people of color who were interested in becoming teachers.

Project UPDATE provides the pathway for paraeducators to work toward an Associate of Arts degree via a curriculum designed to meet the educational challenges of urban schools. The project incorporates a curriculum designed around constructivist methodologies for the delivery of multiculturally rich, technologically relevant courses to adult learners working in urban public education who want to earn a teaching certificate.

UPDATE Scholars, as the preservice teachers became known, continue to work full time as paraeducators while attending college part time. Individuals with little or no college experience begin at STCC and work towards an Associate of Arts degree. Upon completion of their Associate of Arts degree, UPDATE Scholars continue to work toward their Bachelor of Arts degree from the University of Massachusetts-Amherst through the UWW program.

Paraeducators who already have a significant amount of college experience go directly into the UWW program. Through UWW, students may acquire credit for experiential learning. UPDATE Scholars also acquire a Teaching Certificate (Early Childhood or Elementary) through the University of Massachusetts School of Education. Most courses are offered in Springfield at STCC. UPDATE Scholars are eligible for both federal and state financial aid.

Methodology

Description of the Courses

In the first year of project UPDATE, three redesigned mathematics courses were offered at STCC during Summer and Fall 1998: Elementary Algebra I; Elementary Algebra II; and Math for Early Childhood/Elementary Teachers. Sixteen preservice teachers completed these three mathematics courses. Instructors of all three mathematics courses employed a wide range of instructional strategies, which included collaborative group work, problem solving, the use of manipulatives, and calculators. This series of constructivist mathematics courses had a positive impact on preservice teachers' attitudes towards mathematics (Gibson, Brewer, Magnier, McDonald & Van Strat, 1999).

In the Summer of 1999, a non-reformed Principles of Biology course was offered. Fourteen of the preservice teachers who completed the redesigned math courses enrolled in Principles of Biology. This course provided a significant contrast with the three reformed mathematics courses offered during Summer 1998, in that the biology course used a traditional lecture and note-taking approach. This biology course was found to have a negative impact on the preservice teachers' interest in teaching science (Gibson, & Van Strat, 2000).

During Summer 2000, a reformed college level Physical Science course was offered. This course was taught using constructivist instructional methods which included hands-on activities,

manipulatives, real life applications, field trips, group work, and authentic assessments (peer assessments, self-assessments, performance assessments, portfolios and journals). Physical Science is a 4 credit, one semester class that met eight hours per week. The course was designed to introduce students to basic concepts of physical science. Nearly every class included hands-on science activities. These inquiry-based activities were followed-up with classroom discussions and reflective writings. A textbook was used to supplement the in-class activities (Conceptual Physical Science - Hewitt/Suchocki/Hewitt). The textbook was used to reinforce concepts introduced during class activities, and to address many important ideas not specifically covered in class. In addition, students were given weekly homework assignments to engage and challenge them to improve their breath and depth of understanding of physical science concepts.

Journal writing assignments were given at each class meeting. At times journal assignments required students to think about science concepts before formal presentations. At other times, journals were used to make students reflect on observations made in class as well as asking them to make new observations outside of class. Journals were reviewed during one-on-one meetings several times during the term. At the start of class the instructor asked students if they had any comments or questions about their journal assignments. This opening dialog set the tone and provided an introduction to the day's class.

A significant percentage of the final grade was based on self-assessment, peer assessment, and performance assessment. Written quizzes and tests emphasized placed on explanations rather than on recall of facts. In addition, different ways of knowing and teaching scientific ideas were explored. As the final assignment for the course each student was required to select a physical science concept, prepare a lesson, and make a short presentation to the class.

Participants

All fourteen preservice teachers were women and worked full-time as paraeducators in an urban school district. Two were Russian emigrants, one was African American, five were Hispanic, and six were White. Seven of the fourteen UPDATE preservice teachers completed the Introduction to Physical Science course, the three reformed mathematics courses, and the Principles of Biology course. Thirteen were working on their Associate's degree at STCC, while one had already matriculated to the University of Massachusetts Amherst and was working on her Bachelor's degree. Paraeducators take courses during late afternoon and/or early evening to accommodate their work schedules. In addition, many of the paraeducators have children and were single mothers. Usually paraeducators take 3 to 6 credits per semester. All but one of the preservice teachers expressed an interest in teaching at the elementary school level. Only one expressed interest in teaching at the middle/secondary school level.

Data Sources

UPDATE Scholars enrolled in Introduction to Physical Science completed three questionnaires: a *Science Questionnaire* (Rea-Ramirez, Stillings, Vining, & Khan, 2000; Fermann, Stamm, Maillet, Nelson, Codden, Spaziani, Ramirez, & Vining, 2000) and a *Scientific Thinking Survey* (Rea-Ramirez, et al., 2000; Fermann, et al., 2000) and the *Test of Conceptual Understanding* (Appendix). All three instruments were administered twice: once during the beginning of the course, and once near the end of the course. A focus group and an interview were conducted to capture qualitative data on the perspectives of both the preservice teachers and the instructor. Each preservice teacher kept a reflective journal recording her experiences in this course.

The *Science Questionnaire* measures students' attitude towards the teaching and learning of science. It contains 38 statements that preservice teachers were asked to agree or disagree with, on a 6 point Likert scale, ranging from 1 = "Strongly Agree" to 6 = "Strongly Disagree". Students completed the pre-administration of the questionnaire on-line in a computer lab during a class meeting. Due to technical difficulties with the computer lab, post-surveys were administered on paper and sent through the mail to students after the course ended. Differences in preservice teachers' response pre and post identified any change in their attitudes toward science as a result of their experiences in this course.

The *Scientific Thinking Survey* contains four open-response questions that measure critical thinking skills. Each question contains multiple tasks, such as understanding experimental design, identifying underlining assumptions, interpreting graphical information, and designing follow-up experiments. Students completed the pre-administration of the questionnaire on-line in a computer lab during a class meeting. Due to technical difficulties with the computer lab, post-surveys were administered on paper and sent through the mail to students after the course ended. Changes in preservice teachers' responses pre and post to these four items indicated any development in preservice teachers' critical thinking skills as a result of their experiences in this course.

The *Test of Conceptual Understanding* contains 24 questions that measure conceptual understanding of physical science. The physical science course instructor designed this instrument. This questionnaire contains 12 multiple-choice questions, 6 definitions, and 6 open-ended questions requiring a scientific explanation. Preservice teachers completed both pre and post-administrations of the survey during class time. Changes in preservice teachers' responses

to these 24 items were used to identify any change in their conceptual understanding of physical science.

A focus group with preservice teachers enrolled in Physical Science was conducted at the end of the course. The focus group collected information from preservice teachers about project UPDATE and specifically about the Physical Science course. Participation in the focus group was voluntary and no members of the STCC staff were present. The focus group was audiotaped for transcription purposes only. The session lasted about 90 minutes. In addition, an informal interview was conducted with the instructor of the Physical Science course after the course had been completed.

In addition, preservice teachers' journals were collected at the end of the course. For the purposes of this study the journals were photocopied and returned. Also there was an exit survey administered requesting the following information: a) Comment on the usefulness of the journals for learning, b) How would you like to see this class be different? What changes do you suggest? c) What should definitely not be changed?

Results

Science Questionnaire

A paired *t*-test was used to determine statistically significant changes in preservice teachers' responses to items on the pre and post administrations of the *Science Questionnaire*. The following Table presents the five items that where statistically significant differences in preservice teachers' responses to the pre and post survey ($p \leq .05$). Of the fourteen preservice teachers in the physical science course only nine completed the pre and post surveys ($N = 9$).

Table 1

Statements from the Science Questionnaire that revealed statistically significant differences between pre and post survey responses.

Statements
1. Even if I forget the facts I'll still be able to use the thinking skills I've learned in science.
10. The job of science instructors is to explain the things we are expected to know.
14. If there is conflict in science, the most commonly held belief is the correct one.
24. I can do well in science.
37. Lab experiments are used to confirm facts studied in the science class.

The results from this survey indicated that preservice teachers shifted some of their beliefs about science. They went from believing that remembering facts was important to believing that thinking skills were more important. They shifted from believing that the job of science teachers was to explain what students should know to believing that science teachers should not explain what students are expected to know. They went from believing that commonly held scientific beliefs are correct to believing that commonly held scientific beliefs are not necessarily correct. They shifted from believing they could not do well in science courses to believing that they could do well in science courses. And lastly, they went from believing that lab experiments were used to confirm facts studied in science classes to believing that lab experiments are not used to confirm facts.

Scientific Thinking Survey

To determine any differences in preservice teachers' critical thinking skills over time, a paired t-test was used to look at the items on the *Scientific Thinking Survey*. A paired *t*-test

showed that there was a statistically significant difference ($p \leq .05$) in preservice teachers' critical thinking skills between the beginning and the end of the Physical Science course. Preservice teachers pre mean score on *the Scientific Thinking Survey* was 12 and their post-mean score was 19. This data indicates that preservice teachers enrolled in this course improved their critical thinking skills. Individual item analysis of the questions on this survey indicated that preservice teachers' skills improved in the following categories: their ability to analyze data ($p \leq .05$) and their understanding of controls and variables ($p \leq .05$).

Test of Conceptual Understanding

To determine differences in preservice teachers' conceptual understanding of science over time, a paired *t*-test was used to look at the items on the *Test of Conceptual Understanding.* A paired *t*-test showed that there was a statistically significant difference ($p \leq .05$) in preservice teachers' conceptual understanding of physical science between the beginning and the end of Introductory Physical Science. Preservice teachers' pre test mean was 29% correct (7 out of 24) and their post test mean was 50% correct (12 out of 24). These results indicate that preservice teachers' learned some physical science concepts as a result of taking this Physical Science course.

Focus Group

Responses of the preservice teachers during the focus group revealed that the ways the instructional practices used in this course helped the preservice teachers to learn physical science concepts, to improve critical thinking skills, to improve attitudes toward science courses, and to improve their understanding of science. The following are excerpts from the focus group:

> We used a lot of manipulatives in this course and that helped us learn science.
>
> The instructor always made sure to include examples of how physical science concepts were applicable to our everyday lives.

> A lot of time was spent on fewer science concepts.
>
> The instructor made them like science more because of the way the course was taught.

Journals, Exit Surveys and Interviews

Journal entries support the findings that the instructional practices used in this course helped preservice teachers appreciate science in their everyday lives, as well as helping learn science concepts. Their scientific knowledge began to deepen as they developed new understandings. The following are a few excerpts from the reflective journals:

> I want to understand the science concepts we learned about in class today. I never had a true understanding before. I now understand friction, normal force and gravity.
>
> Since this class started I have to admit that I am viewing things differently. For example, I think about chemical and physical changes that happen in my kitchen while I am cooking.
>
> Newton's laws of motion, potential and kinetic energy have more meaning to me now.

Preservice teachers responses on the exit surveys suggested that they found keeping a journal useful to learning. Following are quotes from the exit surveys:

> It helped me think more about what we had discussed in class.
>
> It made me feel safe to express my own opinion. I didn't have to worry about being right or wrong.

Overall, the journals were useful because they made them think more about the science concepts they were introduced to in class. There is no doubt that students need to take time to understand science concepts. The following quotation was taken from the interview with the course instructor:

The use of journals engages students outside of class and keeps their minds on the topics at hand. Keeping a journal requires students to reflect on their learning and this can lead to deeper conceptual understanding.

Conclusions and Implications

The three mathematics courses UPDATE students took during Summer and Fall 1998 were taught using a constructivist approach. This method of teaching had a positive impact on preservice teachers' attitude towards mathematics (Gibson, Brewer, Magnier, McDonald & Van Strat, 1999). In addition, the data indicated that these instructional methods also helped preservice teachers learn mathematics. Constructivist teaching methods improved preservice teachers' attitudes toward mathematics and it also helped them learn mathematics. This user-friendly method of instruction was important to preservice teachers developing good attitudes toward mathematics. In contrast, Principles of Biology taught using a traditional approach (lecture and note taking) had a negative impact on preservice teachers interest in teaching science (Gibson & Van Strat, 2000).

The data presented in this paper indicates that constructivist instructional methods used in Introductory Physical Science had a positive impact on preservice teachers' understanding of physical science concepts, attitude toward science teaching and learning, and critical thinking skills. It is fortunate that these preservice teachers had a positive experience in their Physical Science course especially after the negative experience they had the previous year in the traditionally taught Biology course. The data we have collected, over the last three years, indicates that reformed college mathematics and science courses that use constructivist instructional strategies have had a positive impact on these future educators' attitudes toward mathematics and science.

Research has shown that prospective teachers' attitudes and beliefs toward mathematics and science are key influences on how they teach (Ball, 1990a, 1990b; Moreiri, 1991; Peterson, Fennema, Carpenter & Loef, 1989; Oshima, 1966; Roth-McDuffie et al., 1996; Schoenfeld, 1985, 1989; Silver, 1985; Strawitz, 1976; and Watters & Ginns, 1997). If the educational community wants to increase the number of teachers that can use constructivist instructional strategies to teach math and science then the ways that math and science are taught at the college level must change. Despite programs funded through NSF Collaborative for Excellence in Teacher Preparation such as STEMTEC at the University of Massachusetts, Amherst, traditionally taught college level math and science courses continue to perpetuate the belief that knowledge should be passed down from teacher to student and that learning involves memorizing facts and information. Students are seen as empty vessels waiting to be filled, and teachers should do the filling. Lecturing informs students what they need to know, and students listen and memorize what they have been told.

Many undergraduate science courses continue to be fact-laden, non-inquiry oriented with cookbook laboratories. Because many preservice teachers learned science by attending lectures and taking notes, it is not surprising that they view science as a body of knowledge which they are expected to transmit to children. When preservice teachers finally begin teaching science in their own classrooms, they will remember how they were taught. Many preservice teachers have biased views about how science should be taught. In contrast, research supports the idea that preservice teachers who participate in science courses taught using constructivist instructional methods (inquiry-based) will develop a positive attitude toward science, and this may translate into their interest in teaching science in the elementary classroom. The goal is to prepare teachers who can encourage children to ask their own questions and to allow children to find their own

answers, *not* to tell children a bunch of facts and information about science so they can pass a test.

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Appendix

Pre-Post Test of Conceptual Understanding (This is the first page of a six page instrument)

Give a brief definition for each of the following terms:

Inertia -

Acceleration -

Gravity -

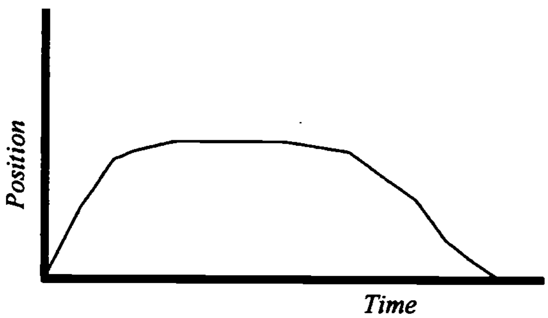
Velocity -

Mass -

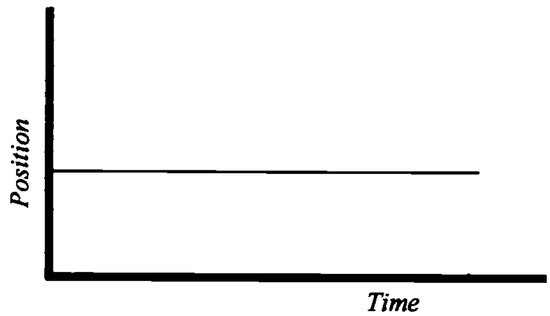
Weight -

Which of the position vs. time graphs below shows an object that ends up at the same place it started? (Select all possible correct graphs)

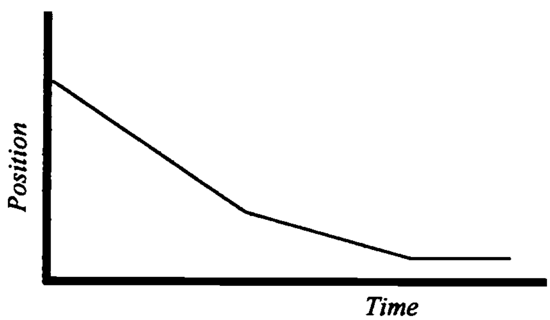
A.



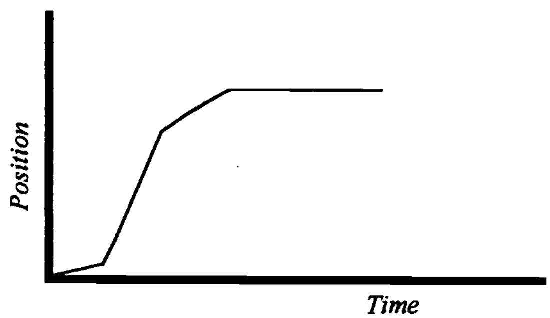
C.



B.



D.



E. None of the graphs.

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