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ABSTRACT

This document contains the abstracts of most of the papers, symposia and poster sessions presented at the 61st Annual Conference of the National Association for Research in Science Teaching (NARST). Subject areas addressed include: teacher preparation, science, technology and society; classroom research; elementary science; process skills; curriculum and instruction; misconceptions; achievement; research in Latin America and the Caribbean; microcomputers; educational policy; problem solving; analytical studies; interpretive research; gender differences; and attitudes. (CW)

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NATIONAL ASSOCIATION FOR RESEARCH IN  
SCIENCE TEACHING - 61st ANNUAL NARST CONFERENCE

St. Louis, Missouri

April 10-13, 1988

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ABSTRACTS OF PRESENTED PAPERS

The National Association for Research  
in Science Teaching

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NATIONAL ASSOCIATION FOR RESEARCH IN  
SCIENCE TEACHING - 61st ANNUAL NARST CONFERENCE  
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## PREFACE

The SMEAC Information Reference Center for Science, Mathematics, and Environmental Education has cooperated with the National Association for Research in Science Teaching to provide abstracts of most of the papers presented at the 61st annual conference in St. Louis, MO., April 10-13, 1988.

All persons who had papers or symposia accepted were invited to submit abstracts for inclusion in this publication. Some editing was done by the ERIC staff to provide a general format for the abstracts.

Everyone presenting a paper at this conference is encouraged to submit to the ERIC Clearinghouse for Science, Mathematics, and Environmental Education a copy of their paper to be considered for inclusion in the ERIC data base. A submission form is included on page iii of this publication. Papers which are not submitted cannot be included in ERIC.

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Patricia E. Blosser  
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Session A1.1: Symposium

SURVEY ANALYSIS OF TEACHERS IN U.S. HIGH SCHOOLS: IMPLICATIONS  
FOR THE PREPARATION AND CERTIFICATION OF SCIENCE TEACHERS

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This symposium describes the results of a survey of U.S. public and private high schools that was conducted in the Fall of 1985. The sample contains 8,539 teachers. Extrapolating from the sample indicates that there were 94,480 teachers teaching one or more sections of science in schools that contain Grade 12. These teachers were responsible for 369,000 sections of science, 22,600 sections of non-science, and 33,300 sections of mathematics. The data reported in this symposium reveal that there are far fewer science courses being taught by non-science faculty than previously believed. Additionally, the profile of a science teacher does not fit the traditional stereotype of a teacher instructing a single discipline.

There are obvious implications of the survey analysis for preservice teacher preparation and certification. Thus, the recently revised NSTA Standards for the Preparation and Certification of Teachers of Science will be introduced. Discussion will focus upon the actual state of science course offerings and instructional loads and the needs of prospective science teachers.

Session B1.1: Paper Set

ASSESSING IMPACT OF STS INSTRUCTION IN 4-9  
SCIENCE CLASSES IN FIVE DOMAINS

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Five domains have been offered to define science education and areas important for student assessment efforts. These five include: (1) knowing and understanding (knowledge domain); (2) exploring and discovering (process of science domain); (3) imagining and creating (creativity domain); (4) feeling and valuing (attitudinal domain); and (5) using and applying (applications and connections domain).

Science/Technology/Society (STS) efforts purport to encourage and facilitate student growth in all five domains. STS has been introduced to 300 science teachers in grades 4 through 9 in Iowa schools during the 1984-87 period. This paper set will focus on student growth in the five domains following use of STS materials and instructional techniques for at least one month's duration. The results are compared with results from other classrooms where STS has not been tried.

The results indicate that knowledge gained is similar - even when the typical topics of textbook and course outline are not followed. The STS program produces significantly better results in terms of student growth in the process, creativity, and attention domains. And, the STS student can apply and connect - something that seems totally missing from standard experience with school science.

Session C1.1: Poster Papers

ASSESSING THE EFFECTIVENESS OF INSTRUCTIONAL MATERIALS  
DESIGNED FOR ELEMENTARY SCIENCE METHODS STUDENTS

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A set of elementary science preservice materials, titled Teaching Children Science, was developed and field-tested during the 1986-87 academic year. The main objectives of these materials are: (1) to assist undergraduate elementary science methods students in developing a working definition of science and the scientific enterprise, (2) to help students learn about effective questioning techniques, (3) to introduce students to the learning cycle, and (4) to demonstrate how the learning cycle can be applied to classroom instruction.

The overall objective of this project was to determine the effectiveness of the preservice materials. More specifically, this project included an evaluation of students' working definition of science, their understanding of effective questioning techniques in teaching, and their approach to developing science lessons.

Sixty-three (63) elementary education majors participated in this assessment. These students were enrolled in one of two elementary science methods courses at the Indiana University School of Education at Indianapolis. There was a different instructor for each methods class. However, the course material and syllabus were the same for each class.

At the first class session of each methods course, the students were given a pretest to assess their background and knowledge in relation to the main objectives of the preservice materials. At the end of the 1987-88 fall semester, the students were given a posttest to assess how effectively the objectives of the preservice materials were met.

The means of the pre- and posttest scores were treated statistically with a t-test to determine whether there was a significant gain in the students' scores after studying the preservice materials, thereby suggesting that the objectives of the materials were met.

## THE EXTRACTION AND REPRESENTATION OF EXPERT KNOWLEDGE OF SEXUALLY TRANSMITTED DISEASES (STDs) IN COLLEGE POPULATIONS

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This paper describes a joint research project between the Department of Computer Science, the College of Education, and the Student Health Center at the University of Maine. The purpose of this work is to analyze and represent expert knowledge of sexually transmitted diseases (STDs) in order to create an intelligent tutoring system for undergraduate students. Modified clinical interviews and concept mapping techniques are used to elicit basic knowledge of STD's from medical experts in this area. This knowledge is then transferred to a computer-based semantic network. Based on these results, a prototype software system is described which can aid experts in the construction of a graphics-based knowledge representation within a variety of content domain areas.

Paradigms are combined from three distinct fields of study. These are cognitive science, to identify, analyze, and organize the domain specific knowledge; software engineering, to develop a well-designed modular research tool; and artificial intelligence, to facilitate design of an automated tutoring system.

## EVALUATION OF A TEACHER INSERVICE TRAINING PROGRAM IN SCIENCE AND MATHEMATICS

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National, state, and local studies indicate a serious under-representation of females and minorities in mathematics and science courses and careers. One way to address this issue is to provide inservice activities which attempt to develop teachers' awareness of the problem and provide them with materials and methods which will improve their students' awareness, confidence, and competence in mathematics and science. This study presents the results of a three-year comprehensive evaluation of a teacher training program named EQUALS that addresses the problem of low participation of females and minorities. The effectiveness of the EQUALS training was assessed using a qualitative method of conducting focused group interviews and using a quantitative method of observing classrooms.

In the fall of 1985, 41 EQUALS-trained teachers from the previous year were grouped by grade level and interviewed. In 1986, 70 more educators participated in similar group interviews. The purpose of the interviews was to characterize the inservice experience. Most of the testimony related to changes in teaching practices. The changes included greater emphasis on problem-solving activities, incorporation of cooperative learning in the classroom, use of problem-solving stations, and greater emphasis on career content. A quantitative study was designed in 1986-87 to determine whether the results of the interviews were corroborated by observational data and, if so, the degree to which the practices were changed. Observers visited the classrooms of six EQUALS-trained intermediate grade teachers before inservice training and after inservice training. A control group of six teachers was also observed. Baseline results indicated no statistical difference between experimental or control groups in average time allocated for any dependent measures.

#### INFLUENCING PRESERVICE ELEMENTARY TEACHERS' VIEWS OF SCIENCE THROUGH SEARCH FOR SOLUTIONS FILM SERIES

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Research indicates that preservice elementary teachers hold a view of science that differs from that held by members of the science community. In general, preservice teachers view science in a less tentative manner than scientists do, and teachers' philosophical views of science may be a major factor in how they teach science in the classroom.

Results indicate that, although a preservice teacher's philosophical view of science could be influenced through a methods class, the generalizability of these results is limited. If readily available films could be evaluated in terms of enhanced teacher outcomes, then science educators would have access to validated effective instructional resources.

The efficacy of one film for bringing about a change in how science is viewed has been validated, while a second study designed to validate the efficacy of another film series shows no significant differences. Possibly the second series did not alter views due to the relatively high beginning scores of the students rather than because the films are not actually effective for altering the way science is viewed. This study further explored the possibility of influencing preservice teachers' views of science by using the Search for Solutions film series.

Elementary preservice teachers in their first education course were randomly assigned to treatment in a Solomon four group design. The

order of the films was random, and the treatment was limited to the viewing of the films. No instructional time was spent on introducing the films or in discussion after the films. The treatment involved the films themselves, not how they were used in instruction.

Data were collected during the Fall 1987 quarter. The posttest was given the first week of December. Dependent and independent t-tests were conducted, comparing pre- and posttest scores.

#### SELF-PERCEPTIONS AND PERCEIVED INSERVICE NEEDS IN SCIENCE AMONG ELEMENTARY SCHOOL TEACHERS

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Professional growth opportunities in science for elementary school teachers typically take the form of summer institutes, graduate studies, or inservice workshops. The focus of these experiences is generally on knowledge in the disciplines of science, processes associated with scientific inquiry, or the methodology associated with some innovative approach to science teaching. Though we have become rather sophisticated in "packaging" and "delivering" inservice education in this way, on what basis do we decide either what content to offer or how to structure long-term interaction between teachers and teacher educators?

In this study an attempt was made to examine an aspect of self-perceptions as a potential organizing principle for developing and presenting inservice opportunities related to science teaching. Previous research indicates that self-referent cognition greatly influence what one chooses to do or avoids doing, how much effort one exerts in a given situation, or the degree of persistence one exhibits with frustrating tasks. Studies in science education show that a significant proportion of elementary school teachers avoids teaching science and expresses a degree of anxiety over the prospect of having to teach science. In accounting for their feelings, teachers cite inadequate facilities, lack of time or resources, and a personal lack of knowledge. On the basis of findings from these two lines of research, studies relating to the sense of self-efficacy or personal control and studies relating to attitudes toward science teaching, it was decided to initiate a study of the relationships among self-perceptions, attitudes, and classroom behaviors among practicing teachers, with a view to better understanding how to tailor inservice experiences to local long-term needs.

Teachers from five schools were surveyed, interviewed, and observed. Instruments used in previous studies with prospective teachers were revised for use with practicing teachers, and scale results pertaining

to self-perceptions and attitudes were compared to perceived inservice needs in science. The self-perceptions examined have to do with the sense of personal efficacy in understanding science, teaching science, and planning science instruction. The attitudes examined pertain to the perceived importance of science education and expectations to teach science.

Finally, regression analysis was used to test the contributions of control orientation, expressed attitudes, and school characteristics to classroom behavior. These findings and their implications for further research and practice are discussed.

### EDUCATIONAL OUTREACH

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In its concern for the declining emphasis on science and mathematics education in this country, the Los Alamos National Laboratory in 1981 developed a series of educational outreach programs to target students (and teachers) in grades 4 through 12 based on existing research that suggested what kinds of activities were most appropriate for each cohort of students. Accordingly, the programs described below were targeted toward distinct groups: students in grades 4 through 6, students in grades 7 through 10, high school juniors and seniors, and high school science and mathematics teachers.

Science Beginnings, a "gee whiz" program for elementary students (grades 4-6), is designed to stimulate children's imagination and interest in science. The program is intended to leave students with a positive feeling towards science, while increasing their knowledge about science. A Monday Morning Science Program brings elementary students to the Laboratory's science museum to expose them to state-of-the-art science and engineering. Careers in Science is a role-modeling program designed to familiarize junior high school students (grades 7-10) with a full range of science and technical careers. The Los Alamos Science Student Program is a program created for motivated high school juniors and seniors to take courses at the Laboratory, taught by Laboratory employees, who volunteer their time to teach state-of-the-art technology. The Los Alamos Summer Science Student Program is an intensive six-week program in which science and technically oriented high school juniors and seniors individually develop, complete, and present a science project with the help of a Laboratory employee who serves as a mentor. The Los Alamos Summer Science Teachers Institute is a four-week program established to help secondary science teachers provide enrichment to their classes by providing them with new knowledge and laboratory techniques. Science Youth Days, an annual event for 30 years, invites students from

schools throughout the Southwest to visit the Laboratory and talk with working scientists. The Summer Teacher Internship Program provides teachers with summer employment to augment their skills through nonacademic assignments in an appropriate area of interest and laboratory project. The program also provides a mechanism for teachers to consolidate their Laboratory experience with subsequent teaching activities.

The success of the Los Alamos National Laboratory's educational outreach programs is due, in part, to the tremendous support from Laboratory management, the interest and involvement of over one thousand Laboratory employees, and the enthusiasm and energy of the program coordinators. Another strong aspect of the programs is the commitment to find out what works and why, and what doesn't work and why, to revise programs on the basis of prior research and empirical research, and to continually evaluate and re-evaluate. In addition, the communities of northern New Mexico have welcomed the opportunity to bring science to the schools and students to the Laboratory.

USER FRIENDLY RESEARCH: AN INTERACTIVE COMPUTER SOFTWARE SYSTEM  
COMBINING TEACHING, LEARNING, CURRICULUM, AND RESEARCH

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This paper describes a joint research project between science educators and computer science software engineers. A computer software system based on cognitive learning theory was designed that is relevant to teaching, learning, curriculum development, and research in science education. The generic prototype software system serves three purposes: (1) it aids instructors and students of science in the construction of a meaningful knowledge base in a science discipline by means of concept mapping; (2) it serves as an intelligent, individualized, and interactive tutor for learning the concepts and conceptual relationships in a specified knowledge domain; and (3) it generates a database for subsequent analysis of, and research on, student misconceptions and how these might change through computer-based instruction. The database generated by the software program can be used to guide subsequent construction, modification, or improvement of curricula.

PERSONALITY TYPE AND QUESTION PREFERENCE  
OF COLLEGE LEVEL STUDENTS

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The impact of personality type on questioning pattern preference is an area of new endeavor. It is the purpose of this exploratory study to determine if a relationship exists between any dimension of personality as measured by the Myers-Briggs Type Indicator (MBTI) and the questioning preference of students. The results of the exploratory study were as follows: persons showing a Thinking preference on the MBTI chose significantly more questions that provide information related to the Sensing dimension of the MBTI, and persons showing a Feeling preference on the MBTI chose significantly more questions that provide information related to the Intuiting dimension of the MBTI. The data seem to indicate that there may be a relationship between personality type and question preference, but more research is needed to describe or define the relationship.

THE EFFECT OF REAL-TIME GRAPHING ON STUDENT UNDERSTANDING  
OF ACID-BASE NEUTRALIZATION

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This experimental study investigated the effect of microcomputer-generated, real-time graphing of an acid-base neutralization on student understanding of the concepts of pH and neutralization. The related concept of instrument calibration was also examined.

The present study extends current research on real-time graphs from middle school to the secondary level and from the physical science concepts of heat, temperature, and light to the formation of pH-related concepts as presented in the secondary chemistry curriculum.

This pilot study involved 13 eleventh grade students who had taken chemistry. The students were divided into two groups: one group used a pH meter; the other group used a pH meter attached to an Apple II+ microcomputer. Each student worked alone, and each student's treatment session was videotaped. Students wore a microphone and a think-aloud protocol was followed. In both groups the students had two tasks: to calibrate the instrument (pH meter or pH meter plus

microcomputer) and to neutralize an acid. For the calibration procedure specific instructions were given, but for the neutralization procedure students were simply instructed to "neutralize the acid."

The microcomputer-based group observed a real-time graph; the pH meter group observed the needle of the instrument swing across the pH scale in response to the addition of acid or base. Both groups received pre- and posttests involving interpreting neutralization graphs. A third group of chemistry students (5) was also pre- and posttested to collect baseline data on knowledge of neutralization concepts. All sessions were videotaped and transcribed.

The groups were not significantly different on their pretest scores. The average posttest scores of both the pH meter group and the non-experimental group rose, but the average score of the microcomputer group declined slightly. It is possible that calibration difficulties caused this decline. Preliminary analysis of the videotapes shows that students in both experimental groups were confused by the concept of calibration. The videotapes also show that students consumed most of their time trying to complete the calibration task.

This is an important finding because any type of instrument, either used alone or in conjunction with a microcomputer to collect real-time data, requires calibration. Successful use of microcomputer-based laboratory (MBL) activities may require explicitly teaching this concept.

#### DEVELOPMENT OF A STAGES OF CONCERN QUESTIONNAIRE FOR PRESERVICE TEACHERS

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The Stages of Concerns Questionnaire (SoCQ) is an established instrument which has been used primarily with inservice teachers involved in innovations. While it focuses on inservice teachers' concerns about an innovation, the instrument is based on theoretical constructs developed by the work of Frances Fuller and others during the 1960s with preservice teachers. The SoCQ has also been used in some studies with preservice teachers. These studies, others using related measures of concerns, and a pilot study by the authors have raised questions about the suitability of the SoCQ in its present form for use with this population. However, the demonstrated usefulness of

the extant instrument and its generalizable theoretical base suggest that such a questionnaire may offer a means of measuring and assessing reforms and innovations in teacher preparation so widely called for and in process at this time.

The purpose of this study is to examine the validity and reliability of a modified version of the Stages of Concern Questionnaire intended for use with preservice teachers in professional preparation programs. Content validity is established through interviews with subjects from the intended population and through reviews by persons conversant with the original instrument. Dual administrations of the revised instrument with the original and the Open-ended Statement of Concerns measures are used to determine the concurrent validity. Developmental and discriminant aspects of the construct validity are approached through pre- and post-administrations to subjects in two different preparation programs (undergraduate and fifth year). Test-retest reliability and interscorer reliability, where pertinent, are also assessed.

The results of these validity and reliability procedures are reported. In addition, recommendations for further refinements and research are made.

#### THE VALIDITY OF SOME GROUP TESTS' TASKS AS A MEASURE OF FORMAL REASONING

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A non-equivalent control group design study, with a math unit of ratio and proportion as the treatment, served to examine the validity of some written tasks as a measure of formal proportional reasoning. The underlying assumption was that tasks that can be performed successfully by young students after a short period of learning mathematical techniques are not adequate measures of formal reasoning.

Subjects in the study were 68 fifth-grade students who were enrolled in two classes in the same school. The experimental group learned a 12-lesson math unit which dealt with techniques to solve ratio and proportion word problems. At the same time, the control group continued to study the regular math curriculum, which at that time was decimal fractions. Pre- and posttests included ratio and proportion tasks from different group tests of formal reasoning.

Findings showed that school learning has improved students' ability to solve " $x/y=c$ " type tasks but did not improve their ability to solve tasks of multiplicative compensation.

Since no improvement was observed in the ability of students in the control group to solve any of the above tasks, it can be concluded that some of the tasks that are used in group tests of formal reasoning are not a valid measure of this cognitive structure.

THE EFFECTIVE USE OF ANALOGIES ON MOLE PROBLEMS  
IN HIGH SCHOOL CHEMISTRY CLASSES

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Students' lack of understanding of the mole concept leads many to resort to algorithmic methods. To counteract this, teachers have used analogies to provide a connection of the mole concept to a more familiar system like the dozen. D. Gabel suggested that the linkage constructed by students themselves should be stronger than that constructed with teacher intervention.

In this study, the effectiveness of teaching the mole concept by using two analogical methods is compared. One group received an analogy treatment in which the teacher explained the connection between the analogy and the chemistry mole concept. The second group received an analogy treatment in which the teacher did not explain the analogy-mole connection but instead left the inference to the students.

Approximately 300 tenth, eleventh, and twelfth grade students enrolled in Talented and Gifted, regular, and introductory chemistry classes were randomly assigned by class to either of the treatments. All teachers taught both methods. Achievement for both groups was measured on a 10-question comprehension quiz on the mole concept administered on the third day of the treatment.

Multiple regression analysis was used to analyze the variability of chemistry achievement scores using the information available on prior knowledge, California Test of Basic Skills Cognitive Scores, and method of presenting analogies.

FACTORS WHICH INHIBIT THE ATTAINMENT  
OF HIGH-LEVEL COGNITIVE OUTCOMES

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This study was an interpretive investigation of factors associated with the acquisition of high-level cognitive outcomes in Grade 10 science classes in which self-paced learning activities were prescribed. Two science teachers from an urban high school in Western Australia volunteered to participate in the study. Each was considered to be an above-average teacher and taught an advanced Grade 10 class with a life science topic scheduled before a physical science topic.

Five researchers utilized participant-observer data-collecting strategies to observe classrooms, interview teachers and students on a daily basis, work with students during class time, obtain written responses to specific questions, and examine student work files and test papers. The validity and technical adequacy of the data were of prime concern during the study. The findings were based on triangulation among data sources and multiple perspectives of the research team, combined with stringent procedures to ensure that efforts to refute assertions were as strong as efforts to support them.

Student perceptions of the psychosocial learning environment were measured in each class with four scales, selected for their salience for this study. Students responded to both the actual and preferred forms of each scale on two occasions: once during the life science topic and once during the physical science topic.

During the last five weeks of the study, the cognitive development of all students was determined using standard clinical interview techniques to assess concrete and formal reasoning ability. In addition, curriculum materials were evaluated on the basis of content accuracy, difficulty, and appropriateness. Instruction, including lectures, laboratories, questions, and tests were evaluated in terms of cognitive level and cognitive demand.

Nine assertions which constitute the findings of the study are:

- The cognitive demand of the academic work was low and required students to participate in low-level tasks such as rote

application of algorithms and recall of factual information. When the cognitive demand of the work was compared to the cognitive ability of the students, there was a mismatch.

- The metaphors which teachers used as a basis for conceptualizing teaching had a strong influence on the implemented curriculum.
- The images projected by the teachers during instruction mediated the learning of students.
- Teachers' content knowledge, pedagogical knowledge, and discipline-specific pedagogical knowledge influenced the way science was taught
- Teacher planning influenced the manner in which science was taught.
- Teachers' beliefs about what students should learn and how they learn have a strong influence on the implemented curriculum.
- Classroom management problems reduced teaching effectiveness, especially in small group and individualized activities.
- Gender differences were evident in both classes in terms of differential involvement of males and females in academic tasks and perceptions of the learning environment.
- Teacher expectations for student performance influenced the manner in which the teachers interacted with specific students.

#### THE TEACHING-LEARNING ENVIRONMENT IN A STUDENT-CENTERED PHYSICS CLASSROOM

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The purpose of this study was to explore how the needs, actions, and beliefs of a teacher and his students interact with the constraints of the classroom and the curriculum to establish an atmosphere conducive to effective learning of physics in Grade 11.

An interpretive research methodology was used to investigate the students' and teacher's needs, ideas, and beliefs which were responsible for the coherent establishment of a harmonious student-centered teaching-learning environment in a Grade 11 physics class. Constraints within the curriculum and the school were examined for their impact on the learning climate. This methodology incorporated data collection, data analysis, and data interpretation procedures throughout the five months of the study which involved cycles of classroom observation and interpretation. The four researchers involved in this study were the classroom physics teacher and three university-based personnel with specific interests in science education, educational psychology, and physics, respectively. One or two researchers were observers in the classroom in addition to the teacher-researcher.

The needs, actions, and beliefs of the teacher and his students and the constraints within the curriculum and the school system were observed and identified and the results presented in a series of assertions:

- Students are mainly responsible for their own learning.
- Activity sheets were used to relate new experiences to prior knowledge.
- The learning environment was designed to encourage student understanding rather than rote learning.
- Activity sheets and note guides are used to engage students in actively constructing their own learning.
- A framework for student learning is developed.
- Additional cues as to the level of cognitive demands come from the students and lead to different classroom strategies being adopted to improve learning.
- The syllabus and assessment structure control the time spent on each topic.
- The learning environment promotes student's self-esteem.

This research highlighted features of this physics classroom which can be used by other teachers to improve their teaching-learning environment to improve physics teaching and learning.

ENHANCEMENT OF PHYSICS LEARNING: TEACHER KNOWLEDGE OF  
CONTENT AND CONTENT-SPECIFIC PEDAGOGY

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This paper describes a study which utilized an interpretive research methodology to investigate the content knowledge and content-specific pedagogical knowledge of one physics teacher and the effects of this knowledge on the learning and classroom activities of his students. The methodology incorporated data collection, data analysis, and data interpretation procedures.

The four researchers involved in this study were the classroom physics teacher and three university-based personnel with specific interests in science education, educational psychology, and physics respectively. One or two researchers were observers in the classroom in addition to the teacher-researcher throughout the six-month study. As a result of the interactions between the researchers and their findings, the teacher was able to reflect on his practice and monitor his teaching.

The paper presents the findings of the study in terms of a series of assertions about the relationships between a teacher's knowledge of content and content-specific pedagogy and about the effects on student learning of physics. Examples of these assertions are:

- the teacher organizes the content to be taught in terms of his knowledge rather than the knowledge presented in the textbook;
- the teacher uses examples and illustrations to take into account students' prior knowledge;
- the teacher is aware of language confusion in physics and everyday speech;
- the research project has affected the teacher's awareness of the need to monitor the classroom environment and of his knowledge of pedagogy;

- students' cannot learn successfully from textbooks without the teacher's content-specific pedagogical knowledge.

There are two major points of educational importance from this study. First, there is considerable pedagogical significance in identifying and documenting the process whereby the content knowledge in the curriculum is transformed by means of the teachers' content-specific pedagogy into comprehensible knowledge by the students. Second, the contribution from an experienced classroom teacher who is an integral and equal part of the research team provided invaluable information about the teaching process. In this study the data from the research team enabled the teacher to reflect on his practice and, where he believed appropriate, to implement changes which were subsequently observed, analyzed, and interpreted by the team. This model of research has implications for involving classroom teachers and for better use of their knowledge in doing research to improve practice.

Session E1.1: Contributed Papers

PRIMARY SCIENCE DIAGNOSIS AND ASSESSMENT  
BY CLASSROOM TEACHERS

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A project was carried out which emphasized a supportive structure between the researcher and classroom teachers to assist them to explore and evaluate suitable techniques for assessing the achievement of their pupils in primary science (taught as a separate subject or in the context of environmental studies).

Eight schools, in which primary science was well established, were selected from a region in Scotland with the help of the Assistant Organizer-Science. From these schools the Heads recommended teachers who were willing to work on this project over one or two terms. In all, 16 teachers from Primary 1 to 7 were involved.

The researcher worked closely with these teachers, visiting them frequently in their classrooms and holding meetings after school and during the noon hour. The philosophy of assessment was discussed with the researcher and sometimes with the Head or Assistant Head, and after much discussion, the teachers drew up tentative plans for assessing their classes in science using the objectives which they had laid out for their units in their forward plans. The assessment techniques were monitored as they were tried out and were, on occasion, modified as the teaching progressed. The techniques selected varied from descriptive checklists to anecdotal comments to assessments of children's work.

Several videotapes were made of children doing science, and a learning package containing relevant material was developed. The paper describes the work of the individual teachers who developed personal and unique assessment techniques to diagnose and assess their children's progress in primary science.

BREAKING DOWN BARRIERS TO TEACHING PRIMARY SCIENCE:  
DID A SUMMER SCIENCE INSTITUTE HELP?

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The purpose of this study was to determine whether obstacles to teaching science primary teachers found before their participation in a Summer Science Institute were changed or surmounted during their involvement in the program. During Summer 1986, ten primary teachers participated in a month-long training session designed to help them improve their background knowledge of light and shadows and develop, teach, and revise a unit on the topic. During the following school year they taught the unit to their classes under the guidance of the Institute director. The teachers' logs, final reports, and post-Institute interviews were analyzed and compared with their pre-Institute interviews to determine how the barriers to science teaching they perceived earlier changed during the year they had participated in the Institute.

Pre-Institute interviews indicated that one of the greatest obstacles was the lack of time to teach science due to the high priority given to reading and math by administrators. This problem had not eased. In fact, there was less time for science for four teachers, due to changes in scheduling, as well as pressures to meet added objectives in reading and math. Nevertheless, the teachers indicated that they would teach science this year.

Lack of materials and equipment was another large barrier before the Institute. Through Title II funds, the teachers had received supplies to teach their light and shadow unit. They reported that having these materials helped immensely. However, they did not receive any school funds for other science materials, and this remained a considerable obstacle.

Assistance in terms of support personnel had improved somewhat. One of the three school districts involved in the Institute had hired a science supervisor. All teachers had new principals, and most were hopeful that the principals would be supportive of their science teaching. As a part of the Institute, the teachers conducted an inservice workshop for other primary teachers in their districts. The workshops were very successful, and some Institute teachers felt that there would be other teachers with whom they could collaborate in teaching science. Parents had shown interest in the light and shadows unit but were generally not concerned about science being taught.

Another problem, that of the teachers' lack of background knowledge, skills, and confidence, showed the most positive change. All teachers, except one who felt confident to begin with, reported that

their participation in the Institute had helped them improve their science teaching, especially in the areas of how to teach and how to manage a class while teaching science. Several reported a transfer of strategies learned in the Institute to other subjects.

The Institute teachers' comments and suggestions, along with those of the university personnel who worked with the program, have important implications for programs to assist primary teachers in teaching quality science.

#### THE RELATIONSHIP AMONG ELEMENTARY SCHOOL TEACHERS' ATTITUDES AND BELIEFS ABOUT SCIENCE AND THEIR TEACHING STYLE

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In a 1984 Gallup poll, teachers ranked improvement in thinking as the most important of 25 educational goals. Popular sentiment toward the teaching of thinking or higher order skills is sweeping the country. But what is the best way for teachers to foster the growth of reasoning skills in their classrooms? Lawrenz and Lawson found that elementary school students gained the most in reasoning ability when they were taught by teachers who were classified as concrete as opposed to formal reasoners. This intriguing and somewhat counter-intuitive result provided the focus for the present study. Why would students of concrete reasoning teachers experience greater gains?

This study begins the attempt to improve the teaching of reasoning by investigating teaching behaviors and characteristics that may be related to a teacher's reasoning ability. This study is the first step in a sequential approach to the problem, and it investigates the degree of clarity concrete and formal reasoning teachers exhibit in their classroom teaching, their attitudes toward science, and their beliefs about science teaching.

The study was conducted on a group of 30 preservice elementary school teachers. They were given a reasoning test, a science attitude inventory (WASP), and a beliefs about teaching inventory (BSSE). In addition, their teaching was observed and rated during an extensive practicum experience and during student teaching to determine the degree of clarity in their presentations.

Paired t-tests were conducted for the four clarity ratings and for the pre- and posttest results on the three scales of the BSSE and the WASP. The concrete reasoning preservice teachers were significantly more committed to the teaching of specific science concepts than were the formal reasoning preservice teachers. The pre- to posttest changes and correlations among the variables were also examined. It appears that commitment to teaching specific science concepts may be a discriminating variable. Also, the results show that there are differences in the way experience affects students of different reasoning levels. The next step in the research, to be undertaken this year, will concentrate on belief systems as related to reasoning style and will utilize more comprehensive observation scales.

A STUDY OF THE RELATIONSHIP BETWEEN COGNITIVE STYLES  
AND INTEGRATED SCIENCE PROCESS SKILLS

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The purpose of this study was to investigate the differences and similarities in the performance of integrated science process skills among the learners divided by their cognitive-style preferences.

In this study, two evaluative instruments were used. The first, the Learning-Style Inventory (LSI) was used to measure individual cognitive styles. Cognitive styles were measured as the two sets of dualities, which were perception types and processing types and their combinations resulting in four learning styles. The second, the Test of Integrated Process Skills II (TIPS II), was used to assess five integrated process skills in science. They were stating hypotheses, identifying variables, operationally defining, designing investigation, and graphing and integrating data. These tests were administered to 107 college students, who were elementary school education majors.

Significant differences in the performance of integrated science process skills among students were found in terms of the students' cognitive-style preferences. The major significant differences in the TIPS II total and subscale score were found among four groups by learning styles. Style I had the lowest achievement in the scores of the TIPS II total and every five subscale. Style II or Style III had the highest achievement in these scores. It could be concluded that a particular type of student achieves better or worse on the different tasks of integrated science process skills. The other significant differences were found between two groups by perception types. Abstract conceptualization type students had higher achievement in the scores of the TIPS II total and two subscales. It could be concluded that performance of integrated science process skills might be influenced by the students' preferences in the ways of perceiving information (concreteness or abstractness). These results might imply that integrated science process skills might be interrelated to the cognitive developmental levels or formal reasoning skills.

Similarities in the performance of integrated science process skills were also found among students who had different cognitive styles. Between two groups by processing types, no significant differences were found in the scores of the TIPS II total and each subscale. It could be concluded that both students who have different processing-type preferences might perform similarly on the tasks of integrated science process skills. In addition to this, similar

tendencies to the score distributions of five subscales of the TIPS II test were found in every group divided by each cognitive-style type. In each group, the score for identifying variables was the lowest and for designing investigation was the highest. These tendencies were commonly found in every group. These results might imply that there might exist an underlying universal cognitive structure which makes the operation of integrated science process skills possible, although cognitive styles are different among students and performance levels of each science process skill might be different among students who have different cognitive styles. It might be necessary to consider the nature of learners for science teaching in general and particular science classroom situations in specific.

#### ASSESSING THE SKILL OF VARIABLE IDENTIFICATION WITH MULTIPLE CHOICE ITEMS

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Increased emphasis on public school accountability has resulted in several states including a science component in their elementary and middle school testing program. This component often includes items designed to measure process skill ability. Testing strategies employed by classroom teachers and district or state level personnel to measure process skill ability may take various forms. Teachers may assess students' level of proficiency by using a checklist during a hands-on experiment or investigation. Another logical method of assessment would be to use items in which an experiment or investigation is described. While both of these methods of assessment may be employed, it is questionable if they are of equal difficulty for students. Not only is process skill ability being assessed with both performance-based observation and multiple choice items, but there exists a great deal of variability within the way multiple choice items are presented.

The purpose of this study was to examine the performance of high school students on four types of multiple choice items used to assess students' ability to identify manipulated and responding variables. Items differed only in the stimulus material presented to students. Stimulus material was either a question focusing on the relationship between two variables, a hypothesis, a description of an experiment, or a description of results of an experiment.

In addition, student performance on these item types was compared to performance on a standard Piagetian interview task of variable identification. The following results were determined from the study:

- 1) The "question" format appears to be the most difficult, while the "results" format appears to be the easiest.
- 2) Although the mean scores on the written manipulated and responding variable subtests were very similar, the correlation between these two subtests was negative. Even though there was a positive correlation between the manipulated interview task and the responding interview tasks, the means of the manipulated and responding interview tasks were not significantly different.
- 3) It appears that the "description" item type had a higher correlation with the total interview than any other item type.

As a result of this study, the following conclusions are tenable:

- 1) Since there was a low correlation between the manipulated and responding variable tests, perhaps knowing how to identify one does not assure that students can identify the other.
- 2) Although all four item types operate similarly, they do not correlate very highly with the interview/observation task.
- 3) If a teacher only assesses students through observation, students may have difficulty in doing well on written tests. Students need to be assessed both with interview/observation and multiple choice tests.

#### THE DEVELOPMENT OF A SCIENCE PROCESS ASSESSMENT FOR FOURTH-GRADE STUDENTS

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In this study, a multiple choice test entitled the Science Process Assessment was developed to measure the science process skills of students in Grade four. Based on the Recommended Science Competency Continuum for Grades K to 6 for Pennsylvania Schools, this instrument measured the skills of (1) Observing, (2) Classifying, (3) Inferring, (4) Predicting, (5) Measuring, (6) Communicating, (7) Using space/time relations, (8) Defining operationally, (9) Formulating hypotheses, (10) Experimenting, (11) Recognizing variables, (12) Interpreting data, and (13) Formulating models.

To prepare the instrument, classroom teachers and science educators were invited to participate in two science education workshops designed to develop an item bank of test questions applicable to

measuring process skill learning. Participants formed "writing teams" and generated 65 test items representing the 13 process skills. After a comprehensive group critique of each item, 61 items were identified for inclusion into the Science Process Assessment item bank.

To establish content validity, the item bank was submitted to a select panel of science educators for the purpose of judging item acceptability. This analysis yielded 55 acceptable test items and produced the Science Process Assessment Pilot 1.

Pilot 1 was administered to 184 fourth grade students. Students were given a copy of the test booklet; teachers read each test item orally to the students. Upon completion of this first administration, data from the item analysis yielded a reliability coefficient of 0.73. Subsequently, 40 test items were identified for the Science Process Assessment Pilot 2.

Using the test-retest method, the Science Process Assessment Pilot 2 (Test 1 and Test 2) was administered to 113 fourth grade students. Reliability coefficients of 0.80 and 0.82, respectively, were ascertained. The correlation between Test 1 and Test 2 was 0.77.

The results of this study indicate that (1) the Science Process Assessment Pilot 2 is a valid and reliable instrument applicable to measuring the science process skills of students in Grade four, (2) using educational workshops as a means of developing item banks of test questions is viable and productive in the test development process, and (3) involving classroom teachers and science educators in the test development process is educationally efficient and effective.

#### A QUALITATIVE ANALYSIS OF STUDENT RESPONSES ON A TEST OF BASIC PROCESS SKILLS

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Currently, the assessment of basic process skills is under the close scrutiny of the educational community. Considerable effort is being put forth by national educational organizations in developing instruments that assess higher order thinking which include both basic and integrated process skills. Methods of assessing these skills, such as paper-and-pencil, station, and interview tests, are also being examined. It is the purpose of this paper to examine student responses on a basic process skills test from a qualitative

perspective and compare student responses with those multiple-choice alternatives provided by the test writers. The data gathered from this study will be used in improving the quality of a Test of Basic Process Skills (BAPS) by providing more viable distractors.

The Test of Basic Process Skills (BAPS) for elementary students measures the skills of observation, communication, classification, measurement, prediction, and inference. This test contains six items of varying difficulty for each identified process skill in a multiple-choice, four-option format. BAPS reliability ( $KR-20 = .82$ ) and content validity were reported in a previous study in which the multiple-choice answers were included.

For this study, the format of the BAPS Test was changed from a four-option, multiple-choice format to an open-ended response format. This was accomplished by eliminating the multiple-choice answers, rewording the question, and providing space for student responses. Additional statements within the test asked students to explain their reasoning in determining their answers. Item complexity and style were not altered.

The open-ended response BAPS test was administered to 29 students in a small, rural Pennsylvania school system in grades 4 through 8. After the students completed the test, the researcher reviewed the individual's test and asked the student how each answer was obtained. Student responses were either written or tape-recorded by the researchers.

Major trends within the group have been examined. The data collected indicate that multiple-choice tests are limited in finding out how a student determines the correct answer. Through the use of open-ended tests, where children are asked to explain how the answers were acquired, reasoning patterns can be studied. In designing tests of basic process skills, it is essential to be familiar with student reasoning patterns and to present distractors that are plausible to the student.

Session A1.2: Symposium

RESEARCH AND CONCEPTUAL BASES FOR REVISING  
THE KARPLUS LEARNING CYCLE

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This symposium will explore possible changes in the original learning cycle developed by Robert Karplus and his colleagues. Recent research and theory outside the confines of the developmental learning paradigm suggest certain changes in this well-known model of science learning. Contemporary cognitive psychology includes many issues such as knowledge representation, storage, and retrieval that are not a part of the developmental paradigm. These issues and related work in misconceptions in science, novice-expert problem solving, and conceptual change theory have implications for any contemporary model of science learning.

Within the developmental learning paradigm, Renner and his colleagues have continued to explore issues such as the sequencing of the three phases of the learning cycle. They have concluded that all phases (exploration, concept invention, expansion of the idea) are necessary, but, for optimum learning, the nature of the concept and whether the student is concrete or formal operational must be considered.

In working to integrate research on misconceptions and reasoning patterns, Lawson has concluded that three types of learning cycles must be provided: (1) descriptive, (2) empirical-deductive, and (3) hypothetical-deductive. The three cycles place different demands on reasoning abilities of students, with the hypothetical-deductive cycle requiring formal reasoning skills. A central component of each learning cycle is the exchange of contradictory viewpoints among students (i.e., argumentation).

It has been proposed by Good that adding a fourth phase, prediction, to the learning cycle would make the model more consistent with modern schema theory as well as offering certain advantages to science

teachers and students: (1) Students are encouraged to organize their existing knowledge of a system (e.g., harmonic motion, predator-prey) by identifying factors which might affect the system; (2) Students become aware that a variety of opinions are held by fellow students, leading to argumentation that Lawson holds is crucial for conceptual change to occur; (3) Students' predictions can serve as information to the teacher about possible misconceptions/naive theories; (4) Prediction carries with it a degree of commitment to check its accuracy, involving both affective and cognitive components of intelligence; (5) Progress of students' understanding can be judged much more accurately if prediction is used at the beginning of a learning cycle.

Research within the science misconceptions and novice-expert problem-solving domains has produced many interesting results and should be incorporated into contemporary science learning models. Future usefulness of the Karplus learning cycle will depend on the extent to which it can be modified in response to contemporary related research.

Session B1.2: Paper Set

EVALUATION OF THE CHEMISTRY IN THE COMMUNITY (ChemCom) CURRICULUM:  
A FIVE-YEAR STUDY OF OBJECTIVES, COGNITIVE DEVELOPMENT, PROBLEM  
SOLVING AND OTHER HIGHER ORDER SKILLS, TEACHERS' PROFESSIONAL  
BACKGROUND AND ROLE, AND STUDENTS' ROLE

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ChemCom is a curriculum designed specifically for the 60 to 70 percent of middle ability high school students, grades 10 and 11. Its development, during the period 1981-1986, was funded by the National Science Foundation and the Institute of Petroleum Chemistry. In 1986 Ronald Anderson reported to NARST on one of the three components of the field test evaluation: "The Role of ChemCom as Seen through a Sampling of Teachers Involved in the Field Testing." The data he reported were collected through ethnographic interviewing.

The entire evaluation includes two major activities: Pilot testing and field testing. The pilot testing involved faculty and two doctoral students in science education at Temple University. The pilot testing was designed to develop and to validate an opinionnaire used in the study and to develop and test the first drafts of end-of-module cognitive tests and a final examination. These tests were modified and used in the field test component in order to determine the extent of increased knowledge of facts and principles of chemistry, as well as the development of higher order thinking skills. These tests eventually were to become an integral part of the published ChemCom "package."

The field testing included three phases:

- 1) A statistical analysis of the end of module tests and final examination
- 2) Assessment of the field test teachers: their science education background, the context in which they were included in teaching during the field test, and their opinions related to ChemCom
- 3) The results of the ethnographic interview (mentioned earlier).

The NARST presentation will:

- 1) describe the procedures followed throughout the evaluation process, giving the rationale for the procedures;
- 2) indicate the results of each of the components of the pilot and field tests; and
- 3) briefly address what the investigators discovered concerning the attempt to integrate natural and social sciences into a single curriculum without compromising the integrity of chemistry content while emphasizing chemistry's laboratory orientation.

Over 2,800 students and 68 teachers from eight test sites across the U.S.A. were involved in the evaluation. Eleven additional teachers taught the year course without pre-implementation instruction, and four classes taught by two teachers served as control groups. Data from 70 percent of the student population involved in the evaluation were usable, and a sampling of one-third of the teachers was involved in the evaluation process.

Session C1.2: Contributed Papers

GENDER DIFFERENCES IN STUDENTS' PERCEPTION OF THE  
SOCIO-CULTURAL ENVIRONMENT IN SCIENCE CLASSROOMS

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An appreciable amount of learning outcome variance has been attributed to the environment in which teaching and learning are conducted. Studies carried out so far have, however, not focused on the socio-cultural aspect of the classroom environment which has been theorized to have potential influence on students' learning. The intent of this study was to examine the influence of five descriptors of the socio-cultural environment in science classes with particular reference to how these are perceived by boys and girls.

The 30 item Socio-cultural Environment Scale was used to collect data from 707 students in secondary grades 4 and 5. Authoritarianism, goal structure, African worldview, societal expectations and sacredness of science were the five descriptors studied. No sex differences emerged when the scores on the Scale were pooled. We, however, recorded sex differences in the societal expectation subscale, most prominently exhibited on the item "My friends expect me to do well in science." Most of the female subjects selected "never" as the option to this item; the reverse was true for boys. This perception is in agreement with the literature on sex differences in science education and projects the social pressure that brings about subject preferences. The implications of these findings for science teaching and further research are highlighted.

A CROSS-AGE STUDY OF STUDENT UNDERSTANDING OF  
FOUR BIOLOGY CONCEPTS

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Do college students exhibit greater understanding of biology concepts than do seventh and tenth grade students? What patterns exist among misconceptions held by students across these three educational levels? What factor does developmental level exert in student understanding of

fundamental biology concepts? One hundred students from each of three grade levels (seventh, tenth, and college) were selected for the study. Concept Evaluation Statements (CES's) were administered to evaluate student understanding or misconceptions of four biology concepts: the cell, diffusion, homeostasis, and gene function. Two Piagetian-type tasks (Letters Task and Ratios Task) were used to determine developmental levels.

Data analysis indicated that college students were more likely to respond to the CES's and to employ scientific terminology than were the two younger groups of students, but the greater frequency of responses did not always mean a greater degree of understanding. Rather, misconceptions in the college group frequently arose from the misapplication of scientific terminology. An increase in student understanding of the concepts of the cell and homeostasis occurred across the three educational levels, but no differences in understanding among the grade levels were found in the responses to the diffusion CES. Few of the students at any level responded to the gene function question. Chi-square analysis of the relationship between developmental level and concept understanding indicated that formal operational students exhibited greater than expected "understanding" of the cell and homeostasis concepts. Concrete operational students showed greater than expected "no understanding" for the same two concepts. No differences were apparent in the responses to the diffusion CES with regard to developmental level. Chi-square analysis of the relationship between student understanding of the gene function concept and developmental level was precluded by the fact that 90% of the concrete operational students and 70% of the formal operational students did not respond to the CES. Generally, developmental level had no effect on the number of student-held misconceptions for any of the four concepts. The frequency of misconceptions was proportional to the number of students that responded to the CES's. As more students responded to each CES, the number of observed student-held misconceptions increased.

AN INVESTIGATION TO ESTABLISH CATEGORIES OF SCIENCE  
MISUNDERSTANDINGS AND TO ATTRIBUTE ANTECEDENTS OF  
MISCONCEPTIONS AND MISPROPOSITIONS

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The purpose of the study was to develop a better comprehension of the general roots of misunderstandings held by middle school students. The content in the form of facts, concepts, and propositions of a unit of instruction appropriate for middle school students was plotted on an instructional content map. On the map, categorical concepts were ordered in hierarchical form, appropriate concepts were connected to define propositions, and important facts were listed. An instrument

was prepared and validated to assess student knowledge of the topic and administered. Initially, the investigation identified and plotted identified misunderstandings on the instructional content map. Secondly, the study gathered evidence that supported the proposed categorical misunderstandings system of misfacts, misconceptions, and mispropositions. Finally, it was possible to attribute misunderstandings in the form of mispropositions to underlying concepts or subordinate or superordinate propositions and to attribute misunderstandings in the form of misconceptions to embedded defining concepts or the inaccurate placement of the concept in a concept hierarchy.

The results of the study suggest general strategies for designing instruction and organizing curricula. The categorical system of misunderstandings provides a framework for future investigations of science misunderstandings.

Session D1.2: Contributed Papers

Toy-Playing Behavior, Sex-Role Orientation, Spatial Ability, and  
Science Achievement of Fifth Grade Students:  
Are They Related?

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Throughout the United States both boys and girls receive the same K-8 science curriculum, yet boys tend to outscore girls on science achievement tests. As the age of the students increases, so do the sex-different science achievement scores. Reasons for these sex-related differences in science achievement may be related to three areas: social, educational, and personal.

Data were gathered from 283 Midwestern, suburban, fifth-grade students. Subjects responded to a newly developed toy-playing inventory, the Tracy Toy and Play Inventory, a modified Bem Sex-Role Inventory, and a standardized spatial ability test. Science achievement scores from the Iowa Tests of Basic Skills-Science were retrieved from students' school records. This correlational study investigated the possible relationships among children's extra-curricular toy-playing habits, sex-role orientations, spatial abilities, and science achievement.

Findings indicated that boys had significantly higher spatial skills than did girls. No significant differences in spatial ability were found among students with different sex-role orientations. No significant differences in science achievement were found between girls or boys, or among students with the four different sex-role orientations. Students who had high spatial ability also had significantly higher science achievement scores than did students with low spatial ability. Femininely oriented boys who reported low-playing in the two-dimensional, gross-body-movement, and proportional-arrangement toy categories scored significantly higher on the test of science achievement than did girls with the same sex-role and toy-playing behavior.

To help promote the development of science achievement and/or spatial ability, increased toy-playing with two-dimensional and gross-body-movement toys may be beneficial for undifferentiated, masculine, and androgynous boys and for feminine girls. Increased toy-playing with three-dimensional toys may be beneficial for masculine and feminine girls and boys. No toy-playing recommendations can be made for estimated-movement-with-a-target or science-activity toys. Promoting androgyny in girls may provide them with more opportunities for intellectual stimulation and development, as they scored well above the mean on the test of science achievement regardless of their toy-playing behavior.

STUDENT KNOWLEDGE OF HEALTH AND FITNESS CONCEPTS  
AND ITS RELATION TO LOCUS OF CONTROL

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Most science curricula include the study of health, but students often leave school without a clear understanding of many health/fitness concepts. While attitudes and skills concerning health may be improved through school science programs, health behaviors are frequently not influenced since students apparently fail to accept responsibility for their personal well-being.

The purpose of this study was to examine students' understanding about health and fitness concepts and to relate their conceptual knowledge to locus of control about these concepts. Following instruction, a sample of Grade 8 and 9 students was interviewed about health/fitness concepts, and pencil-and-paper instruments were used to measure locus of control and knowledge concerning health and fitness. Data were analyzed to determine the extent of the relationship between locus of control and conceptual knowledge. Test and interview data were used to create a two-tier diagnostic instrument that health educators can use to identify students' misconceptions about health and fitness.

Students' knowledge of health and fitness concepts was less than satisfactory. The study provided further evidence of misconceptions about health and fitness, which were used to develop the diagnostic test. This sample of students had a more internal locus of control for their fitness than for their health. Students who possessed high knowledge scores possessed an internal locus of control for both personal health and physical fitness. Conversely, students who possessed low knowledge scores possessed an external locus of control. This relationship may mean that internality of the locus of control construct can be increased through improved knowledge. Such a relationship has important implications for science curriculum writers and science teachers to ensure that school-aged youth do maintain control over their health and fitness.

SCIENCE ACHIEVEMENT AND ATTITUDES TOWARD SCIENCE OF FIFTH  
GRADE STUDENTS IN ELEMENTARY SCHOOLS IN ISRAEL

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Different aspects of science achievement and attitudes of fifth grade students in elementary schools in Israel were found in the second IEA study.

The most significant findings were:

- 1) General attainment can be interpreted as medium (the average score = 60; S.D. = 17; percentage of students passing, the mastery cut-off score = 39; percentage of students failing = 28).
- 2) Attainment in the items defined as actually studied in most of the classes was higher (average score = 68; S.D. = 21; percentage of students passing mastery level = 50; percentage of students failing = 20).
- 3) Higher achievement was attained in physics (Av. score = 63; S.D. = 18; percentage of mastery = 53; percentage of students failing = 24) and in inquiry skills (Av. score = 63; S.D. = 26; percentage of passing mastery level = 58; percentage of students failing = 26).
- 4) The lowest attainment was in chemistry (Av. = 50; S.D. = 26; percentage of mastery = 23; percentage of failure = 50).
- 5) Remarkable attainment in specific content domains was found in biology in topics about the human body, in physics in topics about electricity and temperature, and in inquiry skills in reading and interpreting graphs.
- 6) Noteworthy failures in specific topics were found in mechanics (physics) and density and solutions (chemistry).
- 7) Attainment in items testing knowledge and comprehension was higher by  $\frac{1}{3}$  S.D. than the attainment in items testing application.
- 8) No differences were found between attainment on items representing basic requirements of the curriculum and the test in general.

- 9) Some attainment was found on items which were not studied in most of the schools (Av. score = 52; S.D. = 23; percentage of mastery = 25; percentage of failing students = 54). The subjects in which students displayed out-of school knowledge were the human body and topics which are part of daily experience, such as equilibrium on see-saws, balance, air pressure in tires, transmitting sound through a telephone cable, avoiding rust by painting, etc.
- 10) Great differences between studied and non-studied in-school topics were found in physics and in items requiring only memorization (regardless of topic). It seems that these are the domains upon which schools have a greater impact.
- 11) The only significant gap between the attainment of students from different types of schools was found between advantaged schools and heterogeneous and/or disadvantaged schools. Even after controlling for student ability, a considerable gap of 0.6 = S.D. exists.
- 12) A significant gap (1/2=S.D.) was found between students of Asian-African origin and students of Israeli and Western origin.
- 13) A consistent gap between boys and girls (0.2 S.D., in favor of the boys) was found in most content areas in science.
- 14) Students in fifth grade in elementary school have more favorable attitudes toward science in general than toward the study of science in school and the school in general. Science subjects are less popular than other subjects in elementary school.

IS THE FINAL GRADE IN COLLEGE BIOLOGY A  
TRUE MEASURE OF STUDENT KNOWLEDGE?

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The final grade awarded to a student at the end of a semester is, sometimes, not a true reflection of the person's overall knowledge of the course material. For many, success or failure in a class is determined by how well one does on one or two exams taken during the semester. Disappointingly, many courses do not include intuitive and creative thinking or skill achievement in the evaluation of the student's final grade.

A study was designed to find if the final grade in college biology at a suburban community college was a true measure of the student's knowledge. 170 undergraduates taking the semester course in biology

took part in the study. This population was randomly separated into a control, placebo, and experimental group. The past academic histories of all the participants were checked, and no statistical difference in scholastic knowledge was found for any group.

The progress of the groups was tracked for fifteen weeks. During this time the control group followed a traditional biology scheme of two lectures, one lab, and one seminar each week. The placebo group also followed this schedule but, in addition, was given a 20 to 30 minute presentation on the historical significance of the week's lab. A similar scheme was followed by the experimental group. However, rather than learning about the historical value of the lab, this group was given a specific 20 to 30 minute interaction that had previously been found to enhance a student's visuo-spatial potentials and, therefore, the ability to see things more holistically.

At the end of the semester all the students were given written final exams and lab practicals (an exam that measures the student's skill and understanding of the semester's lab investigations). When an analysis of variance was run on the scores of the final written exam, no significant differences were found. However, statistical differences were noted between the experimental population and the other biology groups on the lab practical. This suggests, therefore, that in the dexteral and implicational aspects of biological knowledge, the experimental group understood the material on a higher plateau than did the students in the non-experimental populations.

When, however, the final grades for the students in the general biology course were statistically examined, no differences between the placebo, control, and experimental groups could be found. This implies that all the groups were equal in their understanding of the course content, a premise that the analysis has shown to be false.

Session E1.2: Contributed Papers

SECONDARY SCIENCE TEACHERS AS CURRICULUM DESIGNERS:  
A CASE STUDY OF TWO ALTERNATIVE MODELS

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Teaching science to poorly motivated high school students has rarely been a preferred task of most science teachers. Since 1980, increased high school graduation requirements have expanded enrollments of poorly motivated students in high school science classes. This case study reports on the work of two groups of secondary science teachers, working separately, to formulate instructional resources for use in high school science classes enrolling a majority of students who heretofore only met minimal science requirements.

The two teams differed in constitution, work location, and duration of interaction. The Consortium team consisted of two high school science teachers from each of three different school districts, two graduate students, and a professor of science education from a major university, all of whom had been high school teachers. The Consortium team met regularly at the university over a period four months. The Village school team included eight high school science teachers from a small school district; this team met regularly in the high school over a period of one month. The Village school team's leadership was shared by a district level administrator and an advanced graduate student at the university. The administrator also was a member of the Consortium team.

The goals of the two teams differed also. The Village school team adopted a charge to assemble resources that would help teachers teach an existing life science course to students in the target population. The charge to the Consortium team was to formulate two instructional units of six to eight weeks duration that would provide a positive example of how to teach science to poorly motivated high school students. Thus, the Consortium team was required to make more decisions about content and teaching approaches than the Village school team, and hence a longer duration of interaction was scheduled.

The two teams differed substantially in the nature of interaction and in the materials produced. Differences between the teams appear to be attributable to: (a) duration over which interactions and work occurred, (b) processes by which team members were selected, (c) purposes and expected outcomes stated for each project, and (d) the amount of discussion on key questions by team members prior to the initiation of materials development.

## HIGH SCHOOL STUDENTS AS COLLABORATORS IN THE DEVELOPMENT OF SCIENCE CURRICULUM

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Two high school students were invited to participate in the revision of a technology curriculum. These students were paid to work through lessons with one of the original authors to provide input for final editing and rewriting. The students were matched to the intended population for which the materials were originally written - poorly motivated students in high school. The two students had a high level of science anxiety as evidenced by their fear of science activities and tests.

Findings indicate that students played a key role in identifying problems stemming from lack of clarity, both of directions and questions. Problems in the sequencing of materials were often noted by the students earlier than by the teacher or other authors. Additionally, students were helpful in the identification and correction of format problems, usually dealing with placement of pictures and charts in relationship to questions and comments.

Perhaps the greatest contribution of the students involved the testing of the practicality of activities and experiments. Some experiments did not work at all, some became workable as group rather than individual endeavors, and some activities even led the students to the wrong conclusion. Finally, students completing the activities gave a good sense of how much time was needed to comfortably complete each activity. Students were helpful in indicating activities and materials that were interesting and what activities actually helped them understand the material.

This collaborative materials revision project was valuable for the teacher-author in giving insight as to how students think - how situations are viewed, how pictures are interpreted, how phenomena are conceptualized, and how questions and directions are decoded.

The trial testing in local schools during the previous year indicated that teachers usually do not do experiments and activities ahead of time and consequently had many problems with the materials. Activities and labs need to be developed to the point where they can stand on their own, able to be completed from the written instructions alone. Writers and authors often already know the material so well that it is difficult for them to identify areas that are problematic to students.

The collaborative process gives teachers and authors insight into student perspectives, which in turn pinpoint problematic areas not easily spotted. Many of the problematic areas arise due to

preliminary assumptions as to students' pre-knowledge, conception of phenomena, and even simple understanding of terms. The collaborative process between teachers and students in the development and revision of science curriculum materials enables the development of higher quality materials that will require less revision at a later time. Moreover, developmental and testing costs are lower and information gained is more detailed when a writer works with two or three carefully selected students than when several teachers engage in trial of the material in their classrooms.

## A STUDY OF THE IMPLEMENTATION OF MANDATED TIME FOR LABORATORY INSTRUCTION

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The educational reform movement has led two states, Texas and Florida, to require that science teachers allocate certain amounts of time to laboratory instruction in secondary science. Texas requires that science teachers in grades 7-12 spend 40 percent of instructional time on lab activities.

In the context of change, the Concerns Based Adoption Model has been helpful in providing the tools to analyze and understand the implementation of changes in education. One aspect of that model, Stages of Concern (SoC), focuses on the developmental nature of the concerns of teachers as they experience change. SoC has proven to be helpful in understanding how changes in science education can be monitored and managed.

Two previous studies of the concerns of Texas science teachers about the 40 percent rule were conducted prior to, and at the end of, the first years of implementation. They showed that Texas teachers are upset with the imposition of the rule and have cast some doubt about the extent to which the mandated program was being implemented. The current study sought to extend the previous studies to the end of the second year (1987) of implementation and to gather information about whether schools have supported the implementation of the rule and the extent to which teachers were implementing the 40 percent requirement.

The results showed that, when compared with previous concerns data, there had been a significant increase in the intensity of concerns about management. These results are encouraging, indicating that concerns about the rule are maturing beyond the previous focus on personal concerns. However, teachers report that while their districts have provided space, materials and supplies for laboratory instruction, they have not provided the staff development needed. Further, Texas science teachers report that neither they nor their colleagues were implementing the rule.

Session F1.2: Informal Discussion

"AN HOUR WITH..."

Rodger Bybee  
NARST Research Coordinator

or

Russell Yeany  
JRST editor

This session on the 1988 NARST program provides NARST members with the opportunity to talk informally with either the NARST research coordinator about possible research activities for the organization or with the JRST editor about the preparation of manuscripts for the journal.

Session A1.3: Symposium

NEW DESIGNS FOR ELEMENTARY SCHOOL SCIENCE

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James D. Ellis  
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Biological Sciences Curriculum Study (BSCS) conducted a comprehensive study of science and health education in the elementary school during the 1986-87 academic year. The two major goals of the study were: (1) to design a framework for an elementary school science, technology, and health program consistent with current educational research, scientific theories, and social trends and (2) to develop a plan for implementing exemplary curricula in science, technology and health in elementary schools.

BSCS staff will review the findings of this year-long design study in three papers that present models for a contemporary K-6 science, technology, and health curriculum, with special emphasis on developing instructional and implementation strategies based on the most recent research in cognitive learning.

INTERVENTION TECHNIQUES FOR INCREASING  
SCIENCE TEACHER EFFECTIVENESS

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The purpose of the paper set is to: (1) examine the problem of science teacher effectiveness through several lines of research on intervention instruction, expert and novice teachers, cognitive modification techniques, and teacher cognition; (2) define and describe results of a series of studies involving intensive instruction (a procedure for cognitive modification) and its effects on teachers and science teaching performance; and (3) describe an intervention instruction program aimed at increasing science teacher effectiveness.

Previous research has indicated that elementary, secondary, and college students, through intensive instruction, can improve their ability to : (1) isolate and identify variables as critical questions and (2) generate hypotheses. All of the studies dealt primarily with a clinical setting.

One of the research studies to be reported investigated the need for effective classroom science teachers to implement strategies that incorporate problem solving. The study explored, through an experimental design, the use of intensive instruction in cue attendance as an instructional technique for improving the problem-solving skills of preservice elementary teachers. Forty-six teachers were randomly assigned to control and experimental groups. The results indicated that the intensively instructed experimental group improved their ability to solve science problems in both clinical and classroom settings. In both instances the subjects performed significantly better for the following dependent variables: (1) identifying relevant details in a scientific problem, (2) asking a more diverse set of questions about the problem, and (3) generating a more diverse and higher quality of hypotheses and tests of the hypotheses. These findings provide additional evidence that the training of preservice teachers to become more critical observers is a functional way to develop successful strategies for solving science problems.

Two additional research studies to be reported were carried out to determine if intervention instruction given to preservice teachers in specific prerequisite cognitive processes transfers to increased performance in planning and teaching classroom science lessons. The instruction involved specific data-gathering processes prerequisite to successful performance in hypothetico-deductive reasoning. Hypothetico-deductive reasoning was seen as crucial to effective decision-making in planning and teaching classroom lessons. The processes involved cue attendance, information search strategies, hypothesis generation, and designing strategies for hypothesis testing. Experimental pre-posttest research designs extending over 5 months were used with 254, grade 1-12, preservice teachers from two separate populations. Significant positive changes were found with instructed teachers' performance in analyzing and writing lesson plans, analysis of classroom teaching episodes, and teaching classroom lessons. Both intervention instruction and overall cognitive functioning levels of the teachers supported more expert teaching performance.

An intervention instruction program aimed at cognitive modification was subsequently developed and used with novice teachers to help correct and re-develop deficient cognitive processes related to unsuccessful performance in classroom planning and teaching. The results of this research series place in perspective the cognitive complexities with which teachers have to deal in classroom settings. Thus, teacher effectiveness in science does not simply relate to being exposed to, or understanding, the content provided in science teacher education courses and workshops. It involves, in addition, the consistent use of higher level thought processes in everyday classroom teaching.

Session C1.3: Symposium

A SYMPOSIUM ON SCIENCE EDUCATION RESEARCH  
IN LATIN AMERICA AND THE CARIBBEAN

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The Ohio State University-Newark  
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Juan Esquivel  
Hugo Mora  
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San Jose, Costa Rica

This symposium will provide a summary and synthesis of the featured presentations, research papers, workshops, and discussion sessions from the Second Consultation on Research in Science and Mathematics Learning in Latin America and the Caribbean, held in San Jose, Costa Rica from December 9 to December 12, 1987. The symposium will be directed toward the examination of research agendas as perceived by representatives of the participating countries and toward mechanisms for networking the research efforts of these countries. Research agenda specific to individual countries and agenda conducive to collaborative efforts will be discussed. Special attention will be focused on how NARST members can become involved in future Consultations and the Consortium collaborative research efforts.

Session D1.3: Contributed Papers

MAINSTREAMING COMPUTERS IN SCIENCE AND MATHEMATICS  
EDUCATION: A TWO YEAR STUDY

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This study summarizes data collection activities associated with the first two years of a large scale NSF-sponsored project involving teachers of science and mathematics with computers. The innovation being implemented in the project is that of using computer-based strategies directly in the teaching of science and mathematics in the classroom and laboratory. During the summers of 1986 and 1987, two separate populations of inservice science and mathematics teachers participated in workshops designed to assist them in the use of computer-based activity teaching for their classrooms. Each group followed a project orientation rather than traditional strategies in learning how to employ computers in the teaching of science or mathematics content. The 1986 group numbered 54 S's, while there were 132 S's involved in the 1987 study. Each group completed the SoCQ instrument developed from the Concerns Based Adoption Model (CBAM). Responses were collected during pre-, post-, and post-post sessions. Pre- and post-responses were collected during the three (or two) weeks of each summer workshop. The post-post responses were collected six months later. For the first year's group, significant reductions in concern were observed using t-tests for three of the Stages of Concern, with Refocusing as the only stage to emerge as significantly more of a concern at the conclusion of the workshop. Post-post responses differed very little, and non-significantly, from the post responses. During the second year nearly the same trends were observed.

INTEGRATING COMPUTERS IN THE BIOLOGY EDUCATION  
OF ELEMENTARY TEACHING MAJORS

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A series of computer-based activities was integrated into the laboratory portion of a two-semester university biology course for elementary teaching majors. The purpose of the project was to improve the biology instruction provided to the students, while at the same time providing examples of appropriate uses of computers in instruction and involving the students in the use and development of

computer-based elementary science teaching materials. Groups completing computer-based activities were compared to non-computer groups on regular class measures of achievement and on measures of attitudes towards computers and the computer-based activities. There were few apparent achievement differences between the computer and non-computer groups. However, there were instances where students gave more favorable evaluation to computer-based activities, and students showed significantly more positive attitudes towards computers as a result of the project. The findings suggest that the integration of computer-based instruction in preservice teachers' science coursework may be an effective means of incorporating computer education in preservice teacher education.

THE EFFECTS OF MICROCOMPUTER-BASED LABORATORY EXERCISES ON THE  
ACQUISITION OF LINE GRAPH CONSTRUCTION AND INTERPRETATION  
SKILLS BY HIGH SCHOOL BIOLOGY STUDENTS

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Effects of microcomputer-based laboratory exercise and level of cognitive development on high school biology students' ability to construct and interpret line graphs was investigated. A mix of quantitative and qualitative methodologies was employed to obtain a thorough understanding of the results. Forty-six students enrolled in general biology classes at a rural high school volunteered to participate in the study. These students were administered instruments to assess the level of cognitive development and line graphing ability. Twenty students who displayed a wide range of abilities in both cognitive development and graphing ability were chosen to participate in the study.

Experimental students experienced four laboratory exercises that utilized a microcomputer to gather, display, and graph experimental data. Contrast students experienced the same four laboratory exercises utilizing conventional laboratory equipment and produced line graphs by hand.

Effects due to instructional method were found on the assessment of the students' graph construction and interpretation abilities. Students experiencing microcomputer-based laboratory exercises outperformed the contrast students on graph interpretation tasks. Students experiencing conventional laboratory exercises outperformed the experimental students on graph construction tasks. Effects due to

cognitive development were indicated with those students classified as high cognitive development outscoring those classified as low. No two-way interactions between treatment and level of cognitive development were found.

Interview and field note data substantiated assertions that students have no precise way to label graph axes and that they believe a best-fit line is a connect-the-dots line. It was also indicated that when students construct a graph, they do not believe a line to represent the data is necessary.

Interview data also revealed that students apply prior knowledge and experience to the conditions presented by the graph and are led to erroneous conclusions about what the graph actually represents. The students also reached improper conclusions about the interpretation of graphs when they improperly scaled axes.

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Session E1.3: Contributed Papers

THE IMPACT OF EXAMINATION POLICY ON TEACHING CHEMISTRY  
IN NIGERIAN SECONDARY SCHOOLS: A CASE STUDY

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This paper presents an account of a dissertation research designed to study the West African Examination Council's (WAEC) policy and its impact on teaching chemistry in Nigerian secondary schools. A tripartite design was used for data collection. First, five knowledgeable public figures in Nigeria and Great Britain were interviewed concerning policy formulation and implementation. Second, five pertinent documents were analyzed. Third, ethnographic methods were used to develop the case study. The case study included an ethnography of the school and classroom level environments at Alanamu (pseudonym) Secondary School, Ibadan, Nigeria. A database was developed from field-notes, data from in-depth interviews and questionnaires (Instruments No. 1 & 2) administered to education officials, chemistry teachers, and school administrators within the Ibadan municipality. Data were also collected with Instrument No. 3, which measured the students' perceptions of the use of available class time in four classes at Alanamu Secondary School. The conceptual framework for the study was Symbolic Interactionism. The analytic framework was Effective Communication. The interview data yielded salient information about the operation of WAEC in West Africa and Nigeria, compared with that of the University of London School Examinations Board (ULSEB) in England. Two main differences were observed, which included first the strong influence of the African government on WAEC's operation, whereas, the ULSEB is not influenced by the British government, and secondly, the issue of security, which has led to examination leakages in African states. The USLEB has no record of leakages.

The study clearly demonstrates the strong impact of WAEC's policy on teaching. Eight-two percent (82%) of the sample surveyed endorsed WAEC's syllabus as a good teaching guide. However, 70% coached their students to pass WAEC examinations. Fifty-eight percent (58%) described their school laboratories as ill-equipped and therefore inadequate for effective teaching. Furthermore, 41% indicated a lack of support from their school administration. Content analysis data showed that WAEC's syllabus (Document No. 1) and the 'O' level chemistry examination (Document No. 2) both emphasized the teaching of "principles and concepts in chemistry" and "the teaching of chemical processes." The percentage of points counted in the two documents for the two curriculum objectives were Document No. 1, 28% and 26%, and Document No. 2, 43% and 20%, respectively. The analysis implied that WAEC's examinations have content validity. School ethnography showed

the failure of teachers to effectively utilize the WAEC's syllabus and recommended textbook in their teaching and the paucity of educational resources in the school. Several implications and conclusions were drawn from the study. First is the need to develop strategies to improve organizational communication in the Nigerian centralized educational system. Second is the need to improve preservice training of chemistry teachers to make them more effective communicators of scientific information. The proposed changes should improve the implementation of WAEC's examination policy in the country.

INFLUENCES OF STATE EDUCATION AGENCY POLICIES, INCLUDING ASSESSMENT,  
ON INSTRUCTION IN SCIENCE IN LOCAL SCHOOL DISTRICTS

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Within this decade, many states have established new policies regarding science instruction in schools. New policies have increased the required number of hours of science instruction, offered greater specification of curricular content, and required more accountability, frequently by mandating state-wide testing of students' achievements in science. Considerable variation exists among states in the nature of the policies adopted, as well as in the way in which policies are supported and/or enforced by state education agencies (SEA). These varied approaches to instructional improvement in different states provided the basis for an informative naturalistic study of the effects of SEA policies on instructional practices in local school districts.

This study was conducted in three states that varied substantially in the degree of centralization of authority, from a high degree of state authority to a high degree of local control. Within each state, one SEA and four school districts (LEA) were the basis of case studies. In each instance, two researchers made two-day site visits to each SEA and LEA to interview staff members and administrators, examine programs, review documents, and make pertinent observations to acquire data on previously specified topics.

Important differences were found in the three states in both the character and degree of influence which SEA's have on LEA's. In addition, it was observed that there were variations among LEA's in each state regarding perceived significance of SEA policies and programs. Case studies in LEA's also point out that SEA efforts pertaining to dissemination of objectives of science instruction and state science assessments (a) influenced science-related activities in most districts studied, (b) broadened the scope of instructional goals in science, (c) gave clearer focus to LEA science activities, (d) stimulated LEA's to move from discussion about science to implementation of science programs, and (e) resulted in increased expenditures in districts for laboratory materials, texts, and staff development related to science.

#### TRANSLATING RESEARCH INTO PRACTICE: A MODEL LINKING UNIVERSITY RESEARCHERS AND CLASSROOM TEACHERS

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The translation of research findings into practical use has been a persistent problem in education. This paper describes a model that seeks to avoid some of the implementation and dissemination practices of the past that produced disappointing results.

The purpose was to develop and test a model that brings together university researchers and classroom teachers in a collaborative endeavor to test, evaluate, and adapt research findings in classroom settings.

The procedure involved three steps:

Step I. Interest Survey: A questionnaire on research interests was sent to a state-wide sample of science and mathematics teachers. Interest in knowing about research results was high among both junior high school and high school teachers. Many teachers expressed an interest in being active participants in research.

Step II. Planning: Survey results were presented to a group of local teachers who had been invited to a meeting to discuss ways to implement the translation of research into classroom practice. As a result of this meeting, a group of seven teachers and three faculty members was formed.

Step III. Implementation: A consensus was reached on operating procedures and principles. It was understood from the beginning that the members of the group would be equal partners in the

enterprise. After study and discussion of research articles, reviews, and other materials, the teachers began trying out ideas from the readings and ideas of their own, reporting results at monthly meetings.

The first group, composed of mathematics teachers and mathematics education faculty members, has met regularly for the past 18 months and met for a three- or five-day workshop during each of the past two summers. A second group, composed of junior high school science teachers and one science education faculty member, was formed after the successful operation of the first group. This group followed the same procedures as the first group but had a different research interest. They are now trying out ideas in their classrooms. A third group is in process of formation. It originated from a class/workshop held on campus where research in cooperative learning was the topic of study.

The first group has now produced a number of classroom curriculum materials for use in integrating the computer into the mathematics curriculum. They have received a grant from a federal agency and will begin to conduct peer training and dissemination activities within another year. The second group has received support from the faculty member's institution; they expect to meet during the summer to produce materials, to develop guidelines for other teachers, and to reach some tentative conclusions about the effects of their work. The third group, still in the process of formation, will have counterparts at two other sites in the state, thus broadening the impact of their work.

It has been shown that there are teachers who are willing to devote their own time to studying and implementing research and that the collaboration with university faculty members is stimulating and energizing, both to the teachers and to the faculty members. When results of research have been tested, evaluated, and adapted by teachers, the teachers can then introduce the innovations to colleagues with a degree of credibility that cannot be attained by an outsider, no matter how knowledgeable or well-intentioned he or she may be. This is a practical and powerful way to carry out the mission of NARST - the improvement of science education through research.

Session F1.3: Contributed Papers

A COMPARATIVE STUDY OF A BIOLOGICAL SCIENCES CURRICULUM STUDY (BSCS)  
STYLE LABORATORY AND A TRADITIONAL LABORATORY APPROACH ON STUDENT  
ACHIEVEMENT AT TWO PRIVATE LIBERAL ARTS COLLEGES

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The purpose of this experiment was to compare an inquiry-oriented Biological Science Curriculum Study (BSCS) style laboratory approach with a more directive traditional approach on student outcomes in the cognitive and affective domains of learning at two private, midwestern liberal arts colleges.

The BSCS approach emphasizes basic and integrated science processes, concept development through extensive questioning, and increased student discretion while the traditional approach contains highly structured, more prescriptive, teacher-oriented activities.

The experimental group (n=60) scored significantly higher than the comparison group (n=59) on adjusted posttest means from scores on a test of biological laboratory concepts,  $F(1,114) = 4.07, p < .05$ . There were no significant differences between group mean scores on a test measuring student attitudes toward science, nor were there any differences between group mean scores on a formal reasoning test. However, both groups experienced an increase in the number of formal thinkers as indicated by pretest-posttest gain scores.

These results lend support to the hypothesis that a BSCS-style laboratory approach fosters desired learner outcomes at the postsecondary level and supports the notion that the laboratory may be used as the primary vehicle to promote formal reasoning skills.

STUDENT KNOWLEDGE OF MODELS AND SCIENCE:  
SOME FINDINGS AND RELATIONSHIPS

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Many science educators are concerned with students' ability to understand science as a process and with their conceptions of scientific knowledge. Preliminary work has shown that the use of a model organizer can result in student perceptions of improved

understanding, but the reason for this effect is not known. This research was undertaken to determine whether students' conceptions of models and the model building process could be useful as an organizer for understanding scientific knowledge and process. Subjects were 687 undergraduate general biology students at a comprehensive southwestern university. These students were asked to respond to two similar sets of six statements referring, respectively, to models and model building or scientific knowledge and process. Responses were reduced to a manageable number of descriptive propositions and analyzed. Results indicate that relationships describing the artificial nature of models could be useful if transferred to the students' conception of scientific knowledge. Such an organizer could be counterproductive in other areas, however, if instruction is not given to expand students' awareness of the full range of models and the process of model-building. Students' knowledge of models was less extensive than might be expected or desired for individuals at this educational level. This points up a possible weakness in the current science curriculum.

EFFECTS OF A SPECIALLY DESIGNED PHYSICAL SCIENCE COURSE ON  
PROSPECTIVE ELEMENTARY TEACHERS' ATTITUDES, KNOWLEDGE,  
AND SKILLS TOWARDS THE LEARNING  
AND TEACHING OF SCIENCE

James E. O'Non  
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A physical science content course was designed to provide prospective elementary teachers with an integrated learning experience that would: (1) improve their attitude toward science and their ability to learn and teach it, (2) increase their knowledge of selected scientific concepts, and (3) develop their skills and appreciation for learning and teaching science. In delivering the instructional model, staff members placed equal emphasis on these three goals.

A major strategy for achieving these goals was the hands-on laboratory experience where the staff members acted as role models for the type of science teaching that they hoped the prospective elementary teachers would adopt for their own science teaching. Staff members sought to demonstrate qualities of good science teaching through integration of selected attitudes, knowledge, and skills.

The research method involved a blend of experimental and ethnographic approaches. The experimental approaches used a pretest-posttest design. These approaches included author-developed background-attitude-skills surveys along with knowledge questionnaires. The ethnographic approaches included open-ended exercises, interviews, and anonymous student written evaluations. Statistical analysis and triangulation were used to determine reliability and validity of the

data. The data were used to generate and evaluate assertions whose conclusions were compared with results reported in relevant literature.

The students in this study were typical of prospective elementary teachers. Benefits to students included a large decrease in science anxiety, a large increase in science enjoyment, a large increase in their understanding and application of their new scientific knowledge, and a dramatic improvement in their appreciation and use of specific science learning and teaching skills.

Data from the study suggest that science courses for prospective elementary teachers should combine appropriate instructional modeling, opportunities for active skill development, and supervised practice of specific science content skills. Integration of these elements appears to be of central importance to success in changing students' attitudes, knowledge, and skills. Implications for practice and future research are given for preservice and inservice teacher education and pre-college science education.

Monday Evening Session: Networking Groups

ATTITUDE RESEARCH

Convener:

Robert L. Shrigley  
Penn State

The major focus of this discussion will be the comparison of persuasion theory (attitude-to-behavior) and self-perception theory (behavior-to-attitude) and how attitude research in science education has been generated, primarily from the former point of view. There will not be a formal agenda; those attending will drive the discussion after a brief introduction.

CONSTRUCTIVIST RESEARCH

Conveners:

John R. Staver  
The University of Illinois at Chicago

Anton E. Lawson  
Arizona State University

The focal points of discussion in this group will be constructivist models of knowledge acquisition and what research based on such models says about improving teaching and learning in science.

ETHNOGRAPHIC RESEARCH

Conveners:

James J. Gallagher  
Michigan State University

Kenneth Tobin  
Florida State University

The use of research on teaching and learning through ethnographic techniques to investigate forces which influence the implemented curriculum will be discussed.

## RESEARCH ON MEMORY SYSTEMS

Convener:

Marianne Betkouski-Barnes  
University of North Florida

The science education community would benefit from a three-step, research-based model that would allow science education researchers, in the final step, to make recommendations to classroom teachers. The first step is to establish an inter-disciplinary approach to research on how the brain and mind learn and remember. The second step, the planning of education research, should be based on comprehensive theory. The third step involves the outlining of actual classroom applications. All three steps must be dynamic and open to new findings.

## SCIENCE/TECHNOLOGY/SOCIETY RESEARCH

Convener:

Peter A. Rubba  
Penn State

Individuals interested in S/T/S education are invited to join in an informal discussion on the directions precollege S/T/S education might take in the coming years.

## USE OF COMPUTERS IN SCIENCE EDUCATION

Convener:

Gerald Abegg  
Boston University

NARST members interested in participating in a sharing session on using computers in research in science education are invited to bring their ideas, software, and related materials.

## INTERNATIONAL SCIENCE EDUCATION RESEARCH

Convener:

Arthur L. White  
The Ohio State University

Collaborative efforts between the United States and other countries will be discussed.

## MISCONCEPTIONS RESEARCH

Convener:

Joseph D. Novak  
Cornell University

Different approaches to misconceptions, preconceptions, naive theories, alternative frameworks, etc. will be discussed and issues related to research will be considered.

## PROBLEM SOLVING RESEARCH

Convener:

Mike U. Smith  
Mercer University School of Medicine

Interest in problem solving in the scientific domains will be discussed. Interests range from documenting the problem-solving performance of various kinds of subjects to teaching problem solving and the development of artificial intelligence tutors. Students interested in problem-solving dissertations are especially encouraged to attend.

Session A2.1: Symposium

ASSESSING SCIENCE TEACHERS' KNOWLEDGE AND THINKING:  
A SYMPOSIUM

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James J. Gallagher  
Michigan State University  
East Lansing, MI 48824

Kenneth Tobin  
Florida State University  
Tallahassee, FL 32306

This informal symposium is designed to allow participants (researchers attending as well as the three organizers/leaders) to (a) share and discuss research strategies they are using for assessing science teacher knowledge in different areas and (b) evaluate the potential of some of these strategies for direct application in preservice science teacher education programs. Each of the three organizers/leaders is currently conducting a study of science teacher knowledge or thinking and will describe that work. The main focus of the session, however, will be on sharing of information and ideas among all session participants currently doing relevant research and on a joint effort to answer the question, "What real potential do these studies and data collection strategies have for changing the content and methods of science teacher education preservice courses?" One of the responsibilities that will be assumed by the three organizers/leaders will be recruitment of a core of people for the session who are involved in pertinent work and who will be encouraged to bring one-page handouts describing or showing an example of a research strategy they have used to diagnose some aspect of science teacher knowledge.

KNOWLEDGE REPRESENTATION IN NOVICE PROBLEM SOLVERS

George J. Pallrand  
Sheila F. Pirkle  
Daulat W. Husain  
Rutgers University  
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This paper-set focuses upon the question of how naive subjects organize and represent knowledge when solving problems. How is the previous experience of a novice used in solving a problem? What kinds of information and knowledge are sought, as well as overlooked by novices, when solving problems? What kinds of strategies do novices employ when solving problems? What cognitive abilities can be associated with the more successful novice problem solver?

The problems selected were based upon a phenomenon about which every individual has some general awareness and common understanding. The problems involved objects shot from a gun into space. The problem series presents a sequence of phases, each of which builds upon the previous one. The sequence requires the subject to restructure the problem elements previously used in a new and extended environment.

The problem sequence is presented to individual subjects via a clinical interview. Once the subject has presented his/her view of the problem phase, it is graphically simulated on the computer screen. The subject can then compare his/her interpretations of events with that generated by the computer. This provides a mechanism for exploring the interactions between the subject's internal representation and those generated with the computer simulation.

Today's research suggests that people have naive notions about problems in motion which can be termed misconceptions, a term which presupposes that the individual has a conception. Everyday phenomena supposedly help to determine and define our conceptions, but do we really have a conception or are these just meager representations, bits and pieces of "frames" of representations? Can we presume that an individual has a concept of a particular phenomenon by the inferences made from life experiences? On the contrary, many scientific concepts are rooted in "envisioning" and not in perceiving things as they seem. Representations based on experiential knowledge are limited in their application and restricted to the particular phenomenon itself. This leads us to assume that novices may not really have a conception at all in the first place. Instead they have misrepresentations which they use as mental models during a problem solving activity. Misconception may be a misnomer; instead, in the majority of cases, there is an absence of conception and/or misrepresentations.

The studies reported involved 10 graduate students in a master's level program for elementary education; junior high school students, identified as relatively field dependent or field independent; and 10 additional graduate students.

Session C2.1: Workshop

HOW TO GET PUBLISHED IN RESEARCH JOURNALS

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This workshop (maximum number of participants - 30) is directed toward the newer members of NARST and the topic, "How to Get Published in Research Journals." However, everyone is welcome to attend. This type of seminar/workshop is one of the most popular pre-sessions offered at the American Educational Research Association (AERA) annual meetings and at many other research-oriented national conventions. Participants are encouraged to bring their own manuscripts for public or private criticism during discussions.

Apparently, many NARST members feel ill-informed and uncomfortable about how successful authors prepare manuscripts directed toward editors of popular research publications. The intention here is to present participants with actual criterial standards used to adjudicate submitted manuscripts, examples of common presentational errors made by authors, and "unwritten" techniques used by successful authors published in professional journals.

Other distributed materials will be used to guide participants in recognizing the need to conform to the stringent standards and conventions currently imposed by today's editors. For example, rationales typically used by authors in the introduction of their work will be analyzed in terms of previous and recent guidelines used by today's journal reviewers. In this regard, many reviewers previously permitted authors to cite works in a vague, tangential, misleading, or second-best source fashion. Now, many reviewers and their editors require authors to go beyond the advice presented in the American Psychological Association (APA) Manual and to follow closely conventions of high standards including properly argued rationales devoid of fallacious reasoning.

A QUALITATIVE ANALYSIS OF SECONDARY SCIENCE  
STUDENT TEACHER BELIEFS AND THEIR CHANGES  
DURING THE INTERNSHIP EXPERIENCE

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This study was designed to utilize qualitative research techniques to determine preservice science teacher beliefs prior to and following the completion of intensive internship experiences and to describe the changes in these beliefs. The data collection and analysis techniques used consisted of the repertory grid technique fortified with factor analysis. Because all of the data were generated by the student teachers themselves, the potential distorting influence of researcher-imposed perspectives was eliminated.

Seven secondary level science student teachers enrolled in a graduate level teacher preparation program participated in the study. All of these teachers had bachelor's degrees in their respective science subject areas.

Data collection involved two sets of interviews conducted both before and after the completion of intensive ten-week spring internship experiences. During the first set of interviews on each occasion, student teachers generated and completed a repertory grid matrix representing their perceptions of typical teacher behaviors and underlying reasons for these behaviors. Each set of grids was factor analyzed using a computer-generated principal components analysis with varimax rotation. During the second set of interviews on each occasion, student teachers reviewed their respective factor structures and developed a label and an accompanying written narrative describing the label.

The factor structures and their teacher-generated interpretations were analyzed on two levels. First, comparisons were made between the organization and content of the factor structures developed before and after the internship experience. Second, comparisons were made between the content, style, and depth of the interpretive narratives written by each student teacher before and after internship experiences.

The narrative descriptions for individual factors ranged in length from 5 to 200 words. For some of the student teachers, the narrative descriptions changed from long, broad, and verbose paragraphs to short, succinct, and concise statements, while for others the opposite trend occurred. The style of the interpretive narratives differed dramatically among different student teachers, even when the factors and component constructs involved were nearly identical.

The results of this study challenge long accepted theories regarding the teacher induction process and corresponding changes in stages of concern. In addition, the findings highlight the complexity and diversity of student teacher belief structures and reinforce the need for further examination of individual, rather than collective or group, belief systems.

## THE DEVELOPMENT OF SELECTED INSTRUCTIONAL AND CLASSROOM MANAGEMENT PRACTICES

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The purpose of this study was to assess and compare selected instructional and classroom management practices of teachers who are graduates of the Post-Degree and Undergraduate Programs in secondary school science at The Ohio State University. The Post-Degree Program is a secondary science certification program for individuals who already have a bachelor's degree in an area other than education. The Undergraduate Program is a more traditional four-year program leading to a bachelor's degree and science certification. Graduates of the two programs were compared with respect to three criterion variables: attitudes toward using inquiry activities, use of these activities in the classroom, and the use of effective classroom management practices. The study also sought to identify teacher characteristics and contextual variables which were predictors of these attitudes and practices.

The sample consisted of 51 full-time inservice science teachers who received teacher certification from the Post-Degree or Undergraduate Program between 1980 and 1985.

Three instruments were used to collect data. The Science Classroom Activities Checklist: Teacher Perception (SCACL: TP) was completed by the teacher graduates to assess their attitudes toward inquiry activities. The Checklist for the Assessment of Science Teachers: Pupil Perception (CAST: PP) was completed by students in the graduate's class to assess the use of inquiry activities. The Student Classroom Rating, also completed by students, assessed classroom management practices. Three questionnaires were used to collect data on teacher characteristics and contextual variables relating to the students, school, and administration. Analysis of variance, analysis of covariance, and stepwise multiple regression were used in the data analysis.

Results of statistical analysis found significant differences between Undergraduate and Post-Degree graduates with respect to their attitudes toward inquiry. Post-Degree graduates held more positive attitudes toward using inquiry-oriented laboratories. No significant differences were found between the two groups in their use of inquiry or effective management practices.

This study also sought to identify predictor variables for the three criterion variables. Results found that teachers who valued inquiry activities were (1) more likely to be humanistic in their pupil control ideology, (2) felt their class size was not a constraint to instruction, and (3) had sufficient administrative support for discipline. Results also found that teachers rated high in their use of inquiry activities were more likely to be effective in their classroom management practices and worked with administrators who provided support for discipline and instruction. In addition, teachers rated high in the use of effective management practices felt administrators should work with teachers in handling discipline problems. These teachers also taught students who felt they learned a great deal in the class relative to other classes.

These findings suggest that effective classroom management is an important condition associated with the use of inquiry activities. The findings also point to the impact that the school setting has on teachers' attitudes and practices. These have important implications for teacher educators and school administrators.

COGNITIVE MODIFICATION AS INTERVENTION INSTRUCTION  
FOR INCREASING BASIC SKILLS IN CLASSROOM  
SCIENCE LESSON PLANNING AND TEACHING

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An investigation was carried out to determine if intervention instruction given to early and middle childhood preservice teachers in specific prerequisite cognitive processes would transfer to increased performance in planning and teaching science lessons. The instruction involved specific data gathering processes basic to successful performance in hypothetical-deductive reasoning. Hypothetical-deductive reasoning was seen as crucial to effective decision-making in teaching science. The processes involved cue attendance, information search strategies, hypothesis generation, and designing strategies for hypothesis testing. An experimental pre-/posttest research design, extending over 5 months, was used with 64 senior year preservice teachers involved in a field-oriented science methods course. Significant positive changes were found with instructed teachers' performance of basic skills involved in analyzing and writing science lesson plans, analysis of classroom science teaching episodes, and teaching classroom science lessons. Both intervention instruction and overall cognitive functioning levels of the teachers supported more expert science performance.

THE EFFECTS OF SLIDE/SOUND COMPUTER-BASED INSTRUCTION  
ON STUDENTS' ACHIEVEMENT AND RETENTION

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Previous studies have documented the effectiveness of feedback in improving students' achievement, but few studies have examined the effectiveness of summaries or reviews. This study examines the respective and combined effects of feedback and review on students' achievement, retention, and level of cognitive development.

A total of 55 ninth-grade students comprised five treatment groups which received an interactive slide/sound computer earth science lesson on "The History of the Earth." All groups received 26 self-test questions throughout the program. The control group received no feedback to their responses to the self-test questions and no reviews for each of the seven sections of the program. One group received non-content feedback for the responses and no reviews, a second group received content feedback and no reviews, a third group received non-content feedback and reviews; and the fourth group received content feedback and reviews. All subjects were given a 28-item achievement test immediately following the computer treatment and the same achievement test one week later.

Results indicated that:

- 1) For the main effect, content feedback produced better results than reviews, and reviews produced better results than no feedback or reviews on students' achievement and retention. (Combined content feedback and reviews produced highest, but not significantly different, means.)
- 2) Achievement and retention difference were attributable to the higher cognitive level questions; no treatment effects resulted from low cognitive level items. Higher level self-test questions provided a predictability for retention.
- 3) Although the amount of informational feedback increased the students' program time proportionately, productivity was significantly greatest for content feedback.

The study concluded that providing students with feedback produced significant increases in achievement, retention, and higher-order learning while a review produced significant improvement only in higher-order learning.

The study suggests interesting implications for the efficiency of the interactive form of science instruction and the impact of higher cognitive level feedback on retention.

RESEARCH ON COMPUTERS IN SCHOOLS:  
FROM PLATO TO LOGO AND BEYOND

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Computers entered the world of public education sometime in the early to mid-1960's. Since then, the number of students gaining access to some sort of computer-based or computer-assisted instruction in grades K-12 has increased exponentially. At the same time, the power and potential uses of computers (now generally micro computers) have also increased exponentially.

This paper reviews 25 years of research on the impact of computers in schools. Prior to 1980, most research in this area was directed at evaluating mainframe-based computer-assisted instruction (CAI) programs, such as PLATO. Researchers followed a quantitative "media-comparison" approach. Their results provided fairly consistent support for the use of CAI for drill-and-practice and tutorials in basic skills such as math and reading. Few applications were found in science teaching.

Since about 1980, microcomputers have entered many classrooms and are dominant factors in curricular development. Research on the role and effectiveness of microcomputer-based education (MCBE) is only now emerging. The variety of potential uses for MCBE in classrooms, and especially in science classrooms, leads to varied research literature. This paper reports on research in three broad areas of current interest: instructional uses, learning to program, and the social context of microcomputers in classrooms.

The "Summary and Implications" section of the paper addresses the potential impact of microcomputers on present and future science curricula. Implications are drawn from the findings of the research review.

## A MODEL FOR IMPLEMENTING MICROCOMPUTERS IN SCIENCE TEACHING

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The Biological Sciences Curriculum Study (BSCS), with support from the National Science Foundation, is conducting a three-year project to develop a model for implementing educational computing in school science. This paper explains the tentative model in detail and presents the results of a pilot test of the model, which project staff conducted during the first year of the project.

The goals for the project are

- to develop and test a model of implementing educational computing in school science;
- to train 260 science teachers and administrators in the Pikes Peak region to use microcomputers to enhance science learning and teaching;
- to establish a network in the Pikes Peak region to implement educational computing in school science; and
- to disseminate a model of implementation for educational computing in school science.

During the first year, project staff and members of the advisory committee designed strategies for training science teachers and for supporting the implementation of educational computing. Project staff conducted a two-day workshop to introduce the knowledge and skills teachers need to integrate educational computing into science instruction. Participating teachers attended four seminars during the school year to practice and refine the skills. Throughout the year, project staff coached the participants as the participants began using microcomputers.

The project met its objectives and was successful at increasing science teachers' use of microcomputers. Project staff gathered descriptive data from the participants to determine background characteristics, prior experience with microcomputers, and prior education in science and science education. Project staff defined and measured implementation according to the Concerns Based Adoption Model (CBAM). Results from pre- and posttests using the Stages of Concern questionnaire indicated that the participants changed from a profile typical of non-users of an innovation toward one typical of users. Project staff developed an Innovation Configuration checklist to describe participants' use of microcomputers. Most of the participants were using microcomputers in several ways by the end of the year. The participants identified barriers to implementing educational computing in science instruction, which project staff used to design implementation strategies for the second year of the project.

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THE IMPACT OF VARYING THE ORDER OF COMPUTER-BASED PRACTICE  
RELATIVE TO HANDS-ON PRACTICE IN LESSONS FOR TEACHING  
MEASUREMENT TO SIXTH GRADE STUDENTS

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The purpose of this investigation is to evaluate the instructional impact of computer enhanced basic science process skill lessons wherein the order of practice modes differs. More specifically, do sixth-grade students receiving "hands-on" measurement practice followed by computer simulated measurement practice differ in performance and attitude from students who receive these measurement practice modes in the reverse order?

Forty students in intact sixth-grade classes received lecture and demonstration instruction on how to make length, mass, and volume measurements. After the two periods required for the teacher to explain and show these basic procedures, students got a chance to engage in two additional periods of measurement practice. The practice involved actual "hands-on" and computer simulated modes. The order of these measurement practice modes was reversed for the two treatment groups to which students were randomly assigned. In one treatment students spent a class period of computer simulated measurement practice, followed by a class period of "hands-on" practice. In the other treatment the period devoted to the computer simulated practice came first.

Soon after the lessons were completed several post-assessments were made. It was found that the treatment group scores did not differ significantly on a twenty-five item measurement concept application test. The numerically higher mean was that of the group receiving the "hands-on" practice first. Further, on an opinionnaire concerning the lessons, an item by item comparison of the responses of the two treatment groups revealed no statistically significant differences. Interestingly, however, for all but one of the ten items the numerically higher mean (more positive opinion) was that of the group completing the "hands-on" measure practice prior to the computer simulated practice.

With the higher numerical mean scores on the post-assessments so frequently in favor of the group receiving the "hands-on" practice prior to the computer simulated measurement practice, a trend in the data is suggested. Further repetitions will be needed to confirm the suspicion of the researchers that, for students of this level, "hands-on" measurement practice followed by computer-based practice is the preferable lesson order.

Session F2.1: Contributed Papers

A PROCEDURE FOR DETERMINING THE LEVEL OF ABSTRACTION  
OF SCIENCE READING MATERIAL

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Classroom teachers frequently express concern that textbooks and other curriculum materials are too difficult for their students. One criterion for textbook selection has been readability level; however, the grade level designation does not necessarily reflect the cognitive demand that concepts within the textbook passages place on students or how well they comprehend the material.

The objectives of this investigation were to: (a) develop a method for scoring the Level of Abstraction (LOA) of science reading material, and (b) explore its relationship with certain other known methods for assessing curriculum materials (passage readability level, student cloze score, and teacher prediction of students' level of comprehension). Also examined were relationships between students' cloze scores and passage readability levels.

The study was based upon nine passages taken from life, earth, and physical science textbooks written at three different levels. Data were collected to obtain preliminary agreement from science educators in the classification of concepts, determine interscorer reliability, and compare student and passage variables.

Participants consisted of 24 science educators, 60 science teachers from elementary, middle, and high schools, and 425 urban students in Grades 5, 7, and 10.

Instruments used were: (a) the procedure to determine level of abstraction developed in this study, (b) the cloze procedure, and (c) "Reading Level, a Program for Teachers," a published computer program which calculates readability levels based upon several well-known methods.

Level of Abstraction (LOA) of printed material is defined as the ratio of concepts having no concrete exemplars to the total number of concepts in a written passage expressed as a percent, and is conceptually independent of readability level.

Non-significant correlations were found between: (a) passage LOA and passage readability level, (b) student cloze scores and passage LOA,

(c) passage LOA and teacher prediction of student success, and (d) student cloze scores and passage readability level. However, the consistent and high but non-significant correlations between LOA and cloze scores combined with the fact that the LOA is based upon deep structure rather than surface structure of written material indicate the importance of further investigation of the LOA in its relationship to student comprehension of written material.

#### DEVELOPMENT OF A PROCEDURE TO ANALYZE THE CONTENT OF SCIENCE TEXTBOOKS

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Science textbooks have long been an item of interest and concern among science educators. These teaching aids are used widely and frequently in science classrooms. Thus, they convey the information that students receive as well as influence how students perceive the scientific enterprise. An overreliance on these textbooks often results in an overemphasis on terminology and vocabulary and presents a false impression of the scientific enterprise.

A procedure has been developed to determine the curricular emphasis in science textbooks. It is explained in a thirty-page manual that will permit the user to assess the relative stress that has been given to: (1) science as a body of knowledge, (2) science as a way of investigating, (3) science as a way of thinking, and (4) the interaction among science/technology/society. Life science, earth science, physical science, biology, and chemistry textbooks were used in the analyses. Interrater agreements of 80% and kappas of .60 were often achieved in the content analyses.

A reliable procedure to analyze curricular emphases in science textbooks will permit us to better understand how others perceive science from these frequently used printed teaching aids. For example, do students find a science textbook more interesting when it stresses application (technology) of science than when it stresses pure science? Do science teachers select science textbooks that stress basic science and avoid those that convey the methods or the applications of science? Answers to these questions will give us a more valid research base upon which to recommend the contents of science textbooks and their selection.

THE DEVELOPMENT AND TESTING OF A DATABASE  
OF ELEMENTARY SCIENCE CONTENT  
AND PROCESSES SKILLS

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The purpose of this research was to develop a catalogue of descriptors identifying both the science subject matter and process skills considered to be part of the K-6 curriculum. Each descriptor in this "universe" set was assigned an identification number and entered into a computer database. This database is being used in a variety of applied investigations. One example is textbook comparisons. In these investigations, elementary science texts are coded using the universal set of descriptors and entered into the computer. A quick run of the program can identify the grade level and amount of coverage specific science content receives in the coded textbook being compared. Another use of the database is in curriculum alignment, the matching of a state's or school district's science curriculum objectives with a textbook series. The district's objectives are coded and entered into the program. The computer then searches for correlations between the objectives and previously coded textbooks. The results can provide the district with some indication of the match between the science presented in the various texts and that called for in their objectives. This same approach is being used to correlate the content of educational films with matching content in published texts. This information allows more informed instructional decisions about the utilization of a film in context with the planned curriculum.

Session A2.2: Symposium

THE PROSPECTS FOR CHANGE IN ELEMENTARY SCHOOL  
SCIENCE AND HEALTH

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This symposium reports the results of a year-long design study of elementary school science and health. We examined the current practices of three groups under the guidance of three questions:

- What is the existing framework for learning science and health?
- What is the existing framework for teaching science and health?
- What is the existing framework for implementing science and health curricula?

We studied national policy-setters, school-based personnel, and specific school communities to answer these questions. The results indicate discrepancies between these groups in terms of what policy and research dictate should be happening and what teachers and learners are actually able to practice. Despite these discrepancies we have been able to develop implementation strategies for an innovative science and health program that reduces the gap between policy and practice.

CURRICULUM TRANSLATION IN SECONDARY SCHOOL SCIENCE:  
AN ANALYSIS OF TEACHER FUNCTIONAL PARADIGM

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The five papers in this set describe a research program designed to examine how an intended curriculum, as described in policy documents and textbooks, is interpreted by teachers and adapted to an established pattern of classroom functioning embodied in what is called a "functional paradigm." The underlying notion of a functional paradigm is derived from Kuhn's original work and from Imershein's extension of the ideas of paradigm and paradigm shift to organizational behavior. The overall objective of the research is to explore the value of the notion of functional paradigms, describe prevailing functional paradigms in secondary science teaching, and show how such paradigms establish the boundaries of classroom functioning and influence the interpretation of curriculum.

The data base for the study consists of document analysis and interviews, along with some 250 hours of direct observations in 23 secondary science classrooms. Initial teacher interviews were designed mainly to obtain teacher interpretations of the intended curriculum as described in the appropriate documents. Subsequent interviews were based on the observations and afforded teachers an opportunity to elaborate on their reasons for engaging in particular activities. The data were analyzed by an iterative process of locating recurring themes in the observation transcripts, using these to derive broad categories under which interpretive accounts could be prepared, and elaborating or modifying these accounts from the interview and documentary data.

The first paper in the set outlines the theoretical framework and describes the data base. This is followed by papers on three major substantive areas derived from the analysis: teacher repertoires, orchestration of the setting, and content coverage and evaluation. Finally, a more general outline is given of what seems to be a dominant and a secondary paradigm for science teaching. The dominant paradigm is based on the primacy of teaching content under a whole class setting. The secondary paradigm appears to be based more on the idea of science as process and requires some modification of the dominant pattern of classroom behavior.

Session C2.2: Symposium

INTERPRETIVE RESEARCH IN SCIENCE EDUCATION

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The symposium focuses on the nature of interpretive research and its applicability to science education. The symposium addresses four main areas of concern. First, the speakers will describe the nature of interpretive research and its associated traditions. Second, the issues associated with validity, generalizability and legitimacy of interpretive research will be addressed. In particular, participants will discuss the issue of whether interpretive methods can be used in conjunction with the traditional approaches to research in science education. Third, problems associated with reporting and publishing the findings of interpretive research will be explored. Finally, implications for graduate level research which incorporates interpretive research methods will be explored in terms of the time required, getting the right committee, writing an acceptable proposal, and at what point in the program should the research commence.

The symposium will consist of a series of brief presentations by the panel followed by interactions among panel members and science educators in the audience.

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Session D2.2: Poster Papers

IDENTIFYING, CLASSIFYING, AND CORRECTING STUDENTS'  
MISCONCEPTIONS ABOUT COMBUSTION

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The purposes of this study were to: (a) investigate the nature of junior high school students' preconceptions and misconceptions concerning combustion of solids, liquids, and gases; (b) devise and use a technique for identifying and classifying these misconceptions in the junior high school population; and (c) develop, implement, and test an instructional unit incorporating the findings of the first and second investigations and what is known about conceptual change to help students overcome their misconceptions.

The results of the analysis of interviews with 30 junior high students show that students hold naive conceptions regarding combustion: most of their answers were descriptions of visible events and there was no attempt at going beyond what is seen or felt. In some cases, students appeared to hold a "phlogiston-like" theory which they used to explain the processes taking place during combustion. The results of a follow-up survey conducted with a stratified sample of 250 students to validate the findings of the interviews show that these misconceptions are common among students at this level. Seventy-one percent of the students surveyed held misconceptions and these were consistent across tasks. An instructional unit using students' prior conceptions and conceptual change techniques is being used to correct the identified misconceptions.

WORLDVIEW AND SCIENCE MISCONCEPTIONS:  
A REPORT ON RESEARCH IN PROGRESS

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In science education the objective is to increase both scientific knowledge and outlook. However, judging from the content and organization of secondary level science textbooks, science instruction begins with the assumption that students enter with a fairly mature scientific outlook. A "prima facie" case for the need to examine students' perceptual frameworks or worldview (i.e., the comprehensive and generally subconscious way in which an individual orders and values his/her world) as a possible factor in science learning and attitude development could be based on the widespread occurrence of science

misconceptions among secondary and college students. This has not been done. The focus of misconception research at present is on elucidating misconceptions and on instructional strategies for supplanting them with accurate scientific understanding. It is implicitly assumed that there is sufficient homogeneity of worldview to allow effective science learning with traditional inquiry techniques. Or, it may be that researchers have assumed that "worldview" is too vague a notion to be of value in science education research.

These assumptions are questioned in the research being reported upon here. Rather, the researcher has developed a theoretical framework that supports the concept of worldview as a critical factor in science education. In an attempt to corroborate the theory, the researcher has developed an instrument designed to test hypotheses deduced from the theory. The research report includes the instrument, dubbed Test of Preferred Explanations, a description of its development and validation, and a discussion of data collected from scientists and college students who took the instrument. The preliminary analyses have lent modest support for the validity of the instrument, and the report discusses plans for further validation studies including the use of Jungian-type as a covariate.

The primary significance of this new avenue of research is the potential for greater understanding both of students and of the imperviousness of some misconceptions to good science instruction.

COMPARISON OF STUDENT ATTITUDES TOWARDS SCIENCE  
OF SELECTED TEACHERS BEFORE AND AFTER  
PARTICIPATING IN AN STS WORKSHOP

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This study is concerned with examining the effectiveness of teachers (who have participated in a Science-Technology-Society workshop) on changing students' attitudes towards science. Teachers participating in four Chautauqua workshops were asked to administer two instruments, Preferences and Understanding and Science and Society, to their students on a pretest basis right after the workshop and then carry out a posttest later on in the school year after they had taught some lessons/units following the STS philosophy. The data analysis of pre- and post-measures for both instruments is done for students of selected teachers. Teacher selection was based on their involvement, enthusiasm, and amount of time they spent with their classes on STS, as assessed by: (1) magnitude of attitude change reflected by teacher questionnaires used pre- and post-workshop; (2) evaluation of teacher activities submitted to staff; (3) subjective evaluation on

pre-determined criteria by project director and other staff. Responses of students of teachers who scored high on the criteria listed above and those who scored low are compared on selected items from the two questionnaires. Comparisons are then performed against the whole group and against results from previous studies.

PERSISTENCE OF MISCONCEPTIONS, MISUNDERSTANDING, AND OTHER ERRORS  
OVER TIME, ACROSS SEVERAL COUNTRIES, AND OVER GRADE LEVELS:  
SOME PRELIMINARY RESULTS FROM THE IEA  
CROSS-NATIONAL SCIENCE STUDIES

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During analysis of IEA's Second International Science Study (SISS) data (1983-1985) and comparison of results with those of the First International Science Study (FISS) (1970-1971), an examination of the erroneous responses to multiple choice items showed that certain choices occurred much more frequently than others. Those choices which were selected by 20% or more of students are termed "popular distractors." Some popular distractors were found to occur with remarkable frequency from country to country and from one grade level to another. In those 10 countries taking part in both the FISS and SISS studies, the popular distractors appear also to persist over the approximately 15-year period covered by both studies.

It is considered that the consistent choosing of wrong responses to the multiple choice items reflect underlying misconceptions and misunderstandings. Since the IEA items were not designed specifically to test misconceptions, other reasons for erroneous responses are also proposed, e.g., widespread lack of opportunity to learn and student unreadiness to function at the cognitive level required for success on a given item.

A number of examples of items showing persistent response to popular distractors are presented, and the possible sources of student errors are discussed.

The IEA studies are the only cases to date of survey research in science achievement conducted at a cross-national level in a sizeable number of countries and with large random samples. Given that the analyses are ongoing and that the items are now in the public domain

and can be re-written by interested researchers, a main value of these preliminary results would seem to be to suggest hypotheses that can be focused more sharply and investigated more thoroughly by a variety of methods.

THE DEVELOPMENT OF A TEST OF ALTERNATIVE SCIENCE CONCEPTIONS  
FOR PRESERVICE AND INSERVICE ELEMENTARY TEACHERS

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The purpose of this study was to develop an instrument to measure the alternative science conceptions of preservice and inservice elementary teachers. The reviewed literature identified studies where children were interviewed and surveyed to diagnose their alternative science conceptions. The data from these studies were compiled and utilized to develop a comprehensive multiple choice test on a variety of topics, including force, heat, mechanics, cosmographics, gravity, particulate nature of matter, change of state, living versus non-living, and plants and animals.

The initial instrument was field-tested with a group of 16 inservice elementary teachers. Subsequent modification of the items resulted in a 23-item test. The test was administered to populations of preservice and inservice elementary teachers in both a southeastern and midwestern state. Item analysis compared the alternative science conceptions between the preservice and inservice teachers.

A COLLABORATIVE EFFORT TO EFFECTIVELY EVOLVE PEDAGOGICAL  
CONTENT KNOWLEDGE IN PRESERVICE TEACHERS

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Too often, teachers enter the classroom with what they consider to be a good working knowledge of their content area when, in reality, most of them lack a true understanding of the nature of science. In addition, they have been neither encouraged nor shown how to apply information covered in education courses to their content area.

Subsequently, as inservice teachers, they are tempted to present science only as a language with a vocabulary to be mastered, not as a course which requires thinking and problem-solving. As a result, a memorization course is taught, not science.

The argument continues. What is needed to remedy the situation of poor student attitudes toward science and negative perceptions of science and scientists? Do science teachers need more background in their content area or do they need more pedagogical information?

To address these issues, this research study tested the premise that preservice instruction should promote organized content knowledge, along with effective teaching strategies for presenting the concepts. In order to implement this idea, a collaborative partnership among a scientist, a teacher educator, and an inservice science teacher was formed.

A course was developed to teach science methods to preservice teachers while they were on-site at a local high school. Instruction was directed by the scientist/science educator/high school science teacher triad. Working as a team, these instructors utilized the pedagogical content knowledge paradigm to develop appropriate teaching behaviors and attitudes in preservice teachers. The goals of the triad were twofold: (1) to assist preservice teachers in conceptually organizing their knowledge of science, and (2) to demonstrate and discuss effective strategies for teaching science from interdisciplinary and intradisciplinary approaches.

To realize these goals, the preservice teachers were encouraged to structure their discipline in an organized, logical fashion, so that they could better understand the schema of what they were teaching and be better able to teach science to their students. In addition, the results from educational research studies and their implications for science teaching were presented and discussed.

Twenty-six subjects were randomly selected from a group of fifth-year college students seeking credentials in areas of science, history, and English. However, the emphasis of this paper is on an analysis of data from the eight preservice science teachers.

Qualitative data were gathered by observing the preservice teachers teach in high school classrooms. Also, pretests and posttests were administered using quantitative measures in the following areas:

- Professional Self-Profile
- Content Knowledge
- Pedagogical Content Knowledge

Pretest results indicated that the preservice teachers felt confident in content area knowledge but had little knowledge in teaching

methodologies and a lack of confidence in applying to their discipline what methodologies they did know. Also, these preservice teachers had difficulty in listing major concepts in their discipline and failed to illustrate or describe schematically how scientific concepts relate to each other.

AN EXAMINATION OF THE USEFULNESS OF A PIAGETIAN APPROACH  
TO DISTRACTOR ANALYSIS: SOME EXAMPLES  
FROM THE IEA SCIENCE STUDY

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One of the factors that has been seen to influence science learning is the stage of cognitive thinking attained by the student. Three relevant levels of cognitive thinking have been proposed by Piaget, with the possibility of transitional stages between these levels. The First and Second IEA Science Tests at the 10 year-old and 14 year-old levels each contain four items for which Bergling has classified the student responses into one of three levels of operational thinking.

This paper examines the data provided by students in 10 countries in both the First and Second Science Studies to group these students according to their attainment of one of the three hierarchical levels of operational thinking. Membership in one of the three levels of operational thinking is employed in an exploratory way to examine the responses of the students on other items in the science tests.

THE SCIENTIFICALLY LITERATE: PERCEPTIONS FROM THE CULTURE

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Much has been written about the topic of scientific literacy during the twentieth century. However, a foundation on which to build curriculum remains unclear. This study is the first of three projects

which attempt to characterize the nature of current perceptions of scientific literacy from multiple perspectives. In doing so, the intent, similar to that of Eisner in his five orientations to curriculum, is to expand one's options in curriculum planning by creating an awareness of existing orientations to scientific literacy.

The study is an ethnography of a culture of people, the scientifically literate. The intent was to learn from the people who belonged to that culture. Thirty-two people volunteered to participate in the study: twelve professors, nine teachers, and eleven undergraduates. The major data collection tool was the ethnographic interview, as described by George Spradley.

Overall, three themes were addressed by the majority of participants: how one views scientific literacy; how one demonstrates scientific literacy daily, either personally or professionally; and what influenced one becoming scientifically literate. From these data, a "map" citing various orientations to scientific literacy was outlined.

#### THE EFFECTS OF MICROCOMPUTER-BASED LABORATORIES ON SCIENTIFIC EXPLORATION

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New technology has evolved a new strategy in teaching concepts through laboratory science: the microcomputer-based laboratory (MBL). Many researchers believe that MBL applications have removed much of the drudgery that is often part of laboratory investigation, allowing the student to focus more clearly on the scientific phenomena under investigation and to perform original investigations. The purpose of this research effort is to investigate the effects of the microcomputer-based laboratory on the scientific exploration of middle school students and to establish a knowledge base for subsequent research.

In analyzing the statements made by experts in the field of microcomputer-based laboratories, three questions concerning scientific exploration required research:

- 1) Do students who interact with MBL equipment and curriculum generate more unique trials than without those materials?
- 2) What is the relationship between laboratory mode and teacher intervention on the number of unique trials?
- 3) What is the relation of the number of trials to the level of understanding of the concept?

The study consists of 2 X 2 X 2 factorial design with laboratory mode, teacher intervention, and student ability as the independent variables. The dependent variables are the number of unique experimental trials and achievement score. Achievement score is defined as the adjusted posttest achievement score on the content studied (reflection and refraction of light) with the pretest as the covariate. The test items require skills in scientific problem solving focused on exploration.

Students from three middle schools were involved in the study. The children in each class were randomly assigned to a lab group stratified by ability level. Each lab group consisted of two children, one boy and one girl. The lab groups were randomly assigned to one of two laboratory modes (stratified by ability): one that uses MBL and one that does not. At each level of laboratory mode and ability, the lab groups were randomly assigned to one of two teacher intervention (TI) modes. In one TI mode, the teacher provided only technical assistance in the laboratory. The teacher in the second TI mode additionally prompted the student lab groups by asking questions concerning possible experimental outcomes when the students appear to have completed the laboratory. The computer and observers recorded all decisions the students acted upon during each trial, as well as the number of trials.

Upon the completion of the laboratory unit, the posttest was administered. A three-way analysis of variance was used to analyze the data. Research questions one and two used the number of unique experimental trials as the dependent variable, whereas research question three used the adjusted achievement score.

CHANGING STUDENTS' EXPLANATORY FRAMEWORKS CONCERNING THE NATURE  
OF LIGHT USING REAL TIME COMPUTER ANALYSIS OF LABORATORY  
EXPERIMENTS AND COMPUTERIZED EXPLANATORY  
SIMULATIONS OF E.M. RADIATION

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This study is based on Kelly's Personal Constructs theory in which people are seen as scientists who explain and predict future events by building tentative models and evaluating these models by means of personal criteria. It was assumed that students hold conceptual frameworks prior to the beginning of formal learning.

A series of learning situations rooted in theories of conceptual change was developed for use with 17-year old students. The research program involved three stages:

- 1) Identification and analysis of students' prescience conceptual frameworks on light, based upon discussion about demonstrations of light phenomena.
- 2) Development and implementation of a series of laboratory learning situations in which experimental phenomena examined by the student are accompanied by real time computer-based analysis.
- 3) Identification and analysis of change and of the process of change in students' conceptual frameworks.

Results from student interviews, laboratory experiences, and computer simulations will be discussed.

### INFORMAL SCIENCE EXPERIENCES AS INDICATORS OF SCIENTIFIC LITERACY

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Two stages in research on scientific literacy are identified: a composite saturation stage in which definitions covered all aspects of science education and a stage where researchers focused on small manageable portions of scientific literacy. Envisaged scientific literacy research in which the focus is on cognitive preference for science and informal science teaching is described. Underlying cognitive preference is a valued preference for science. Three interdependent but clearly distinguishable forms of science teaching (formal, non-formal, and informal) are described. Informal science teaching is identified as condition for and outcome of scientific literacy. An instrument to ascertain scientific literacy as manifested through informal science experiences is described.

### ELECTRONIC DATA ACQUISITION, COMPUTERIZED GRAPHING, AND MICROCOMPUTER-BASED LABS: CAN ELECTRONIC DEVICES ENHANCE GRAPHING SKILLS AND CONCEPT ACQUISITION?

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Microcomputer-based laboratories (MBL) - the use of microcomputers for data acquisition, display, and analysis - represent a promising development in science laboratory instruction. MBL include probes

interfaced with a microcomputer which are used to collect and graphically display data from science laboratory experiments. Recent studies have explored the benefits of MBL in the science laboratory but have not looked into the separate distinct capabilities which MBL provide for students in the laboratory: (1) electronic data gathering capabilities and (2) computer-generated graphing. The purpose of this study is to determine whether the advantages of MBL are due to the electronic data gathering capability, the computer graphing ability, or both.

High school laboratory experiences were designed to vary in computerized assistance in two ways: (1) in the method for measuring temperature (laboratory thermometer, electronic digital thermometer, computer probe) and (2) in the way the results were graphed (hand-graphing, delayed computer graphing, real-time computer graphing). The control group used laboratory thermometers and hand-graphed the results. Treatment 1 used a digital thermometer and hand-graphed the results. Treatment 2 used a digital thermometer with delayed-time computer graphing. Treatment 3 used a computer probe and delayed-time computer graphing. Treatment 4 used a probe and real-time computer-graphed the results.

All students ( $n = 120$ ) were pretested on general graphing skills and understanding of science concepts dealing with boiling point and melting point. Students were pretested as intact science classes within the regular high school science classroom. On the day of testing students were transported by bus to the university's educational computing facilities. Pairs of students were randomly assigned to groups to work with the control or one of the four treatments. Each group of students followed written instructions for measuring and graphing the melting and boiling points of two substances, water and salt water. Preservice secondary school science teachers aided students as they worked through the laboratories. Treatments lasted two hours. Written posttests were administered the next day in the regular school classroom.

Posttest performance on graphing skills and conceptual understanding were adjusted using pretest scores. Effects of different treatments were analyzed by ANOVA procedures. Conclusions were made regarding the overall effectiveness of electronic data gathering and computerized graphing. Implications regarding the use of computerized assistance in the secondary science laboratory will be discussed.

ATTAINMENT OF SUPERORDINATE GOALS IN S/T/S EDUCATION:  
EXPECTATIONS AND REALITY, AN EX POST FACTO  
PILOT RESEARCH OF A CASE STUDY

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Recently, several perspectives for a conceptual framework and organizers to guide the development and implementation of both S/T/S curricula and appropriate teaching strategies have been advanced in response to the need felt world-wide for a re-definition of the purposes of science education for all. This new orientation is associated with new goals. An issue of major concern in contemporary research in science education is the assessment of such goal attainment. The course, Science and Technology 11 (ST 11), which was implemented in 1986 in the Province of British Columbia was aimed at achieving three superordinate goals in the S/T/S context.

The main objective of the present "ex post facto" pilot study was to assess whether, and to what extent, these goals have been attained in reality. A "short version" of Views of Science, Technology, and Society (VOSTS) Form MC.4 questionnaire has been administered to 12th-graders who did take (the experimental group) and did not take (the control group) ST 11 in the school year 1986/87. Data concerning the gender and science course history of the respondents have also been collected. The responses to the questionnaires have been used to construct S/T/S response profiles of the two groups and subgroups within, and these in turn served as the basis for data analysis and interpretation of the findings.

707 results will be presented and discussed in terms of both the impact of ST 11 on the S/T/S viewpoints of senior high school students and the possible effects of some key factors including some student characteristics. Preliminary, first approximation conclusions concerning expectations and reality of goals' attainment in S/T/S education have been derived and will be critically discussed.

Session E2.2: Contributed Papers

APPLYING THE COGNITIVE CONFLICT STRATEGY FOR CONCEPTUAL CHANGE:  
SOME IMPLICATIONS, DIFFICULTIES, AND PROBLEMS

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The implications of constructivist theories of conceptual change for instructional design have been vividly summed up by various authors. As a result, science teachers seem to have been provided with explicit and applicable instructions concerning the teaching of concepts and principles. This paper deals with some practical implications of the instructions presented and with some difficulties and problems encountered while trying to implement them.

The opportunity to be involved in situations where we could try to induce conceptual changes was provided during research projects concerning misconceptions in biology. The misconceptions were identified by means of written tests and interviews.

The interviews became in fact mini-lessons given to small groups (3 to 4) of 10th-grade students, who were expected to provide the answers to two questions concerning what to teach and at which level. One question was: Did the students possess the intellectual abilities and the background scientific knowledge necessary to reach a stage of meaningful and relevant cognitive conflict in the specific case under consideration? And, how could this conflict be formulated? The second question was: Did the students possess the intellectual skills and the prerequisite scientific knowledge necessary to replace their preconceptions by new, intelligible, scientifically acceptable ones in the specific case under consideration? And, what would these be?

It was found that decisions about what and at which level to teach scientific topics may be based on the principles of conceptual change. The parameters of the decision are the type of knowledge which the students input into the process, their ability to reach a stage of meaningful conflict, and their ability to resolve the conflict in a scientifically acceptable way. The implications of the new knowledge in terms of students' thinking must be considered. Different topics may bring about different learning situations and different responses from the students. Furthermore, the ability to be successfully involved in an active, constructive process of learning may depend not only on cognitive factors but also sometimes mainly on attitudes of the student toward school and toward school knowledge.

## MISCONCEPTIONS ABOUT GRAVITY HELD BY COLLEGE STUDENTS

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This study is part of a continuing exploration of the naive misconceptions of students in the physical sciences conducted within the context of current literature in alternative frameworks.

During interviews about the nature of the solar system, the subject invariably turns to gravity. This appears to be an exceptionally salient topic to our subjects and one about which they are very uncertain.

The sample was selected from among those students registered for a liberal education physical science class at a small private college. The method used was a clinical interview, beginning with very open-ended questions, moving to that of "interview-about-instances," and ending with a paper-and-pencil test.

Most subjects had some grasp of the concept that the mass and gravity of an object were related. However, there were a variety of interpretations of this. A common one was that, since the gravitational force acted from a point at the center of the planet, it was diminished at the surface as a planet became larger. A slightly different but related inference was that the increasing mass and increasing diameter cancel one another with the result that all planets have the same gravitational force at their surface.

It is not surprising that no person had a clear idea of the origin of gravity. About half of those interviewed knew that it is a function of the mass of an object and could relate this in some way to both size and composition. The remainder offered explanations involving temperature, friction, the ozone layer of the atmosphere, etc.

The presence of the sun appears to be a major factor in the judgments made by most students. Almost all of those interviewed reached their conclusions on the basis of some concept of Newton's laws of universal gravitation. However, for them, the most salient relationship was between the sun and planets. Only one was able to express a relationship for the attractive force between a planet and an object on its surface, and that was not correct. For all of those

interviewed, including even those who had a reasonably good intuitive understanding of this subject, the distance from the sun was the most important factor in making judgments about gravity. The size and nature of the planet in all cases seemed to be much less significant variables.

It is heartening to note that only one person interviewed had no reasonable concept of gravity. For the remainder, we anticipate that the observed misconceptions could be corrected by an appropriately designed intervention.

#### MIND THE RED HERRINGS: DELIBERATE DISTRACTION OF PUPILS' STRATEGIES SOLVING MULTIPLE CHOICE QUESTIONS IN CHEMISTRY

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When working on stoichiometrical problems, students make use of the strategies they have learned from books or from the teacher. But it is well observed that many of them tend to introduce their own strategies, which often are not correct. In pretested multiple choice questions wrong strategies lead to certain distractors.

In the paper it will be shown how through paper-and-pencil tests the wrong strategies of students, primarily working on stoichiometrical problems, have been reconstructed. To validate the results, the wrong strategies have been used to explain the distraction given in examination board papers from outside Germany. Using the results of this analysis, new test items have been designed in such a way that students, while working on the problems, have to handle figures, which fit the right answer as well as the wrong ones. The newly constructed multiple choice tests were given to students. It was well observed that, in solving these items, students followed the strategies which had been the basis for the construction of the multiple choice tests.

Session F2.2: Contributed Papers

THE INFLUENCE OF PREVIOUS ACHIEVEMENT, ATTITUDE,  
WAIT TIME, AND SUPPORTIVE INTERVENTION ON  
PERFORMANCE IN BIOLOGY AND CHEMISTRY

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This analysis investigated the relative influence of previous achievement in science, attitude, perceptions of science classes, and the interventions of wait time and supportive feedback on achievement in biology and chemistry. The data were collected as part of a project on the improvement of high school science teaching through research applications.

Forty-four experienced high school teachers, 22 each in chemistry and biology, participated. The data were analyzed by means of correlated factorial modeling procedures outlined by Lohnes. Variates, in order of entry, were initial demographics, pre-treatment attitude and perceptions, pre-treatment discourse variates, treatment (wait time and/or supportive intervention), discourse variates, and post-treatment attitudes and perceptions. The criteria were scores on conceptual tests and New York State Regents Examinations. Separate, correlated factorial models were calculated and analyzed for each subject.

Most striking is the pervasive influence of the pre-treatment variates on all subsequent observations. Initial demographics, such as high marks in previous science classes, influenced the criteria directly but also exhibited influence through pre-treatment perceptions and attitudes, pre-treatment discourse, discourse during treatment, and post-treatment perceptions and attitudes. Pre-treatment perceptions, including positive science attitudes and low levels of divergent thinking had direct links to final examination scores. Pre-treatment discourse also had an effect on discourse during treatment and on post-treatment perceptions and attitudes as well as on the criteria. The treatment had little effect on subsequent discourse, perceptions and attitudes, or on the criteria, either directly or indirectly.

On the basis of these analyses, it can be concluded that: (a) student achievement in both courses is primarily a function of student attitudes, previous achievement, and discourse variables during the first three weeks of class; (b) while the treatment had influence on discourse and student perceptions, they did not directly influence

achievement as defined in this study; and (c) the relationship of teacher behaviors, student perceptions and achievement, and discourse were more complex than previously hypothesized.

THE RELATIONSHIP BETWEEN ABSTRACT CONCEPT ACHIEVEMENT AND  
PRIOR KNOWLEDGE, FORMAL REASONING, AND SEX AMONG  
SOME EGYPTIAN SECONDARY SCHOOL STUDENTS

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The purpose of this study was to investigate the relationship between the achievement of some abstract concepts in molecular genetics as a dependent variable and a set of the following three independent variables: (1) prior knowledge; (2) formal reasoning; and (3) sex.

The data were collected using 160 third-grade secondary school students drawn from one public school in the city of Idku, Egypt. The subjects were administered three tests. The first test was used to measure students' prerequisite knowledge concerning the topic of genes and nucleic acids. The second test was used to measure the achievement of abstract concepts included in this topic. The Test of Logical Thinking was used to measure formal reasoning. The statistical treatments used in the study were: (1) Pearson product-moment correlation coefficient; (2) multiple regression procedure; and (3) stepwise method.

The major findings of the study were (1) the prior knowledge was correlated significantly highly with the achievement of abstract concepts ( $r=.74$ ,  $p<.0001$ ); (2) the correlation between the formal reasoning and the achievement of abstract concepts was found to be relatively moderate and significant ( $r=.53$ ,  $p<.0001$ ); (3) sex was found to correlate significantly ( $p<.05$ ) but low with the achievement of abstract concepts; (4) the set of the three independent variables succeeded in predicting the achievement of abstract concepts ( $R^2=.63$ ,  $p<.0001$ ); (5) the stepwise method selected prior knowledge, formal reasoning, and sex in the first, second, and third steps respectively; and (6) a relatively high percentage of variability (about 60%) in the achievement of abstract concepts was accounted for by prior knowledge and formal reasoning.

The major conclusions of this study are: (1) prior knowledge and formal reasoning play a major role in students' achievement of abstract concepts; and (2) the effect of students' prior knowledge on this achievement seems to exceed that of formal reasoning.

SCIENTIFIC KNOWLEDGE ACQUIRED OUT OF SCHOOL  
BY ELEVEN YEAR OLD PUPILS IN ISRAEL

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The present study explores the achievements of primary school pupils in two aspects of science: domains taught in school and domains not studied in primary schools of Israel. Information about learning materials used in each class and further detailed information from classroom teachers as to the actual topics underlying specific test items which pupils had opportunity to learn in class enabled the delineation of topics not studied in school and the measurement of attainment in them.

Several topics which are part of the international curriculum are not studied in the first five grades of elementary science classes in Israel. Some of the topics are reflected in learning materials but are nevertheless not actually studied in class. Most of the missing topics in the Israeli curriculum are in physics (levers, equilibrium, sound, motion, air pressure, and gravity). Other missing topics are as follows: in earth sciences, astronomy; in biology, the human body and environmental adaptation; and in chemistry, oxidation.

In all the above domains there is an achievement gap in favor of the topics which are studied in school. The largest gap lies in physics (1.0 S.D.). Only a small gap was found in biology.

The most significant achievement in topics not studied in school was found in biology. About 60% of the student population correctly answered items which they had not had the opportunity to study in their classes. In physics and chemistry the attainment was lower (40%) except for items which are connected with daily experience, i.e., tire pressure, home-made telephones, bouncing balls, weight scales, etc. Particularly high achievement in "non-studied items" was found in the upper quartile of students, while the lower quartile exhibited considerably less achievement. No significant differences of achievement were found between boys and girls.

Apparently, even in science, commonly assumed to be a highly school-dependent subject, much knowledge is gained outside of school. An examination of the topics so acquired suggests that they may be related to children's everyday experiences. Children in the upper quartile on science achievement tests are those most able to exploit these learning opportunities and to relate them to academic areas of knowledge.

No differences were found between boys' and girls' ability to exploit outside-school learning experience. This suggests that the world experiences of both sexes are equally valuable for acquiring scientific knowledge.

Session A2.3: Symposium

CLASSROOM-BASED RESEARCH ON SCIENCE TEACHING  
IN PANAMANIAN HIGH SCHOOLS

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This symposium reports on a two-year joint project designed to increase science education research capacity at the University of Panama. This project was conducted in conjunction with science education faculty members from a major U.S. university and included four faculty exchange visits between the two universities to provide for intensive training and supervision in the use of research techniques.

A team of University of Panama science faculty with strong interest in science teaching and experience in Piagetian research expressed interest in new approaches to research on teaching and teacher education as a way of improving the quality and effectiveness of science instruction. During Spring and Summer 1986, training workshops were organized to (a) provide 20 faculty members with knowledge of the theory and techniques of school ethnography and (b) provide supervised practice in ethnographic research in schools. Follow-up training sessions were held in Fall 1986 and Winter 1987.

As a result of these initial training efforts, four discipline-based teams of faculty members conducted detailed studies of teaching practices in science classes in selected Panamanian high schools. Papers comprising this symposium will include the following: "Strategies for Development of Research Capacity in Classroom-based Research on Science Teaching," "Studies of Secondary School Physics Instruction in Panama," "A Study of Secondary School Chemistry Instruction in Panama," "A Study of Secondary School Biology Instruction in Panama," and "A Study of Geometry Teaching in Selected High Schools in Panama."

Investigations followed the ethnographic model of observation, interview, and document review but without pre-formed hypotheses. The

first stage in these studies was to provide richly detailed descriptions of science teaching practices. Later stages focused on identification of patterns and regularities among observations and sought to understand the forces which have shaped practices. Among the findings of these investigations, it was noted that:

- Whole class instruction is the most frequently used approach to secondary science teaching in the Panamanian high schools studied.
- More emphasis is placed on learning vocabulary and facts of science than on learning principles and applications of science or higher order thinking skills.
- Teachers justify whole class instruction on the basis of time limitations and expectancies of students, administrators, and parents.
- Laboratory work is not a central part of science instruction, even though laboratory assistants were available to help teachers with preparation and delivery of labs.

Other findings, implications for teacher education, and recommendations for practice will be discussed. Research training needs for university faculty members also will be assessed by the participants.

Session B2.3: Contributed Papers

GENDER DIFFERENCES IN ACHIEVEMENT IN COSTA RICAN STUDENTS:  
SCIENCE, MATHEMATICS, AND SPANISH

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Gender differences have been reported in the United States in the areas of mathematical reasoning favoring males and verbal abilities favoring females (Macoby and Jacklin, 1974). Results from the National Assessment of Educational Progress Science Assessment also have consistently revealed small gender differences favoring males.

This paper reports gender differences in Costa Rican elementary and secondary schools and discusses some of the possible mechanisms related to the development of these differences in the Costa Rican context, especially those pertaining to the scientific area.

Gender differences are reported for mathematics, science, and Spanish. The grade levels were: 4th, 6th, 7th, 10th, and 11th. The data for this analysis were collected as part of larger studies on evaluation of the teaching of the subject matters executed by the Research Institute for the Improvement of Costa Rican Education (I.I.M.E.C.) from 1982 to 1986.

Results indicated that at the fourth-grade level, there were no significant differences in any subject matter. The boys had significantly better achievement in science and math than did the girls for 6th, 7th, 10th, and 11th grade levels. On the other hand, the girls surpassed the boys in the same grade levels in Spanish, except for 10th grade where no significant sex differences were found.

The identification of gender-related differences in achievement in mathematics is consistent with the findings reported in the United States. Results for the verbal skills area (Spanish) are also consistent with previous research. The lack of gender differences at the tenth-grade level is unexpected in view of the pattern of results in this area and requires further exploration.

Results for the science assessment also reproduced findings in the United States. With respect to the possible mechanism related to the development of these differences, researches in the science achievement area have suggested several hypotheses, which include consideration of differences in prior instruction in response to uncertainty on item presentation and/or on attitudes toward science.

With respect to the impact of prior instruction, the curriculum for science education in Costa Rica does not allow for differences in

course-taking, i.e., all students are required to take the same course in science up to the grade levels included in this assessment.

Previous research in the area of attitudes toward science indicated that no gender-related differences were found in this respect.

The consideration of differential response to uncertainty and to figurally presented items have not been studied at present. Costa Rican National Assessment tests do not include the "I do not know" response, and no studies have yet addressed the impact of item presentation. As a result of this study the "I do not know" will be included in the 1988 National Assessment in all three areas and the item presentation impact will be considered in future research at I.I.M.E.C.

### SEX DIFFERENCES IN THE SECOND IEA SCIENCE STUDY: U.S. RESULTS

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This project consists of an analysis of U.S. data collected during the Second IEA Science Study (SISS). It specifically focuses on the differences in achievement scores between female and male participants at Grades 5, 9, 10, 11, and 12. A manipulative process test, as well as the written achievement test, was administered to students in Grades 5 and 9. Grade 10 and Grade 11 students who participated were enrolled in first-year biology or chemistry. Grade 12 was divided into students taking physics, those taking advanced science courses (biology, chemistry, and physics), and those not enrolled in any science course. The major findings can be summarized as follows:

- Sex differences have been found at every grade level and in every subject area in the written science achievement tests. This sex difference always favors males. Overall sex differences remain fairly constant, in the 5%-7% range, for all populations surveyed, with the exceptions of Biology-1 (3.1%) and the non-science population (3.8%).
- The fact that some female students have female science teachers does not appear to increase their level of achievement in all content areas. In some cases, having a female teacher has a negative relationship with science achievement for girls, while in biology, having a female teacher has a positive relationship for both girls and boys.
- There appears to be no sex difference in the results of the manipulative tests of process skills which were administered to both fifth and ninth-grade students.

The fact that sex differences were found in the scores of the written achievement tests was expected. The lack of sex differences in the manipulative tests was surprising. This encouraging outcome leads us to recommend the utilization of process-oriented learning tasks as a more sex-equitable method of teaching science.

## GENDER DIFFERENCES IN STUDENT-TEACHER INTERACTIONS IN PHYSICAL SCIENCE AND CHEMISTRY CLASSES

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The study examined classroom factors that may affect the underrepresentation of women in high school and college physics and calculus courses and in physical science and engineering professions. Gender differences in student-teacher interactions, classroom atmosphere, and classroom behaviors were examined. Thirty physical science and thirty chemistry classes containing a total of 1332 students were observed, using the Brophy-Good Teacher-Child Dyadic Interaction System, a quantitative coding process that allows for examination of patterns of interactions for individuals and groups of pupils. Qualitative data on classroom atmosphere, class demonstrations, and teacher verbal patterns were also recorded.

Analysis of variance of the data yielded a significant main effect for teacher praise, call-outs, procedural questions, and behavioral warnings based on the sex of the student. Significant two-way interactions were found for the behavioral warning variable for teacher sex by student sex and subject by student sex.

The qualitative data on classroom conditions and student-teacher behavior revealed that male students were more likely to participate in science classroom activities and they were more likely to be asked by teachers to carry out science demonstrations. There was evidence that teachers continue to sex type science occupations and reinforce the traditional role of the woman as the homemaker. Only a very few female scientists were depicted in classroom posters or displays, and the majority of these were of black female scientists.

Session C2.3: Contributed Papers

A SUMMARY OF INFLUENCES ON ATTITUDE TOWARD AND ACHIEVEMENT IN  
SCIENCE AMONG ADOLESCENT STUDENTS

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During 1978 a comprehensive study to examine home, school, and individual influences on attitude toward science and achievement in science among adolescent students was proposed. In 1979 the study was funded by the National Science Foundation, and extensive data were collected during the next two years.

The three major categories of independent variables addressed in this study were related to home, school, and individual characteristics. The two major dependent variables were attitude toward science and achievement in science.

Within this large population of students from grades 6-10, attitude toward science dropped each year. The greatest drop always occurred from the beginning to the middle of the year. There was also a steady decline in attitude across grades, from sixth through tenth, with an overall attitude at the end of the tenth grade being near neutral. Attitude toward science was consistently higher among boys.

Declines in achievement motivation were markedly similar to declines in attitude toward science. Motivation dropped both within each grade and across grades 6-10 and by the tenth grade was near neutral. Motivation to achieve in science was consistently higher among girls.

Adolescents' attitudes toward science were highly positively correlated with their friends' attitudes toward science. This relationship peaked in the ninth grade.

A major insight that can be gained by examining the results of this study is that the science curriculum and practices currently operating in our schools are not collectively producing students with positive feelings toward science nor many students who are electing to take high school level courses in science beyond minimum graduation requirements. Students in this study, by the end of the tenth grade, exhibited near neutral motivation and attitudes toward science and, for the most part, did not elect to take chemistry, physics, and other courses in science. What this profile suggests is that the average American youth enters middle or junior high school with a less than

adequate science background, experiences the first two or three formal science courses, becomes significantly less positive toward science, and then by high school is prone to take only the minimum requirements for graduation.

TRADITIONAL COSMOLOGY AND ITS INFLUENCE ON  
STUDENTS' ACQUISITION OF THE SKILL  
OF SCIENTIFIC OBSERVATION

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The importance of observation is undeniable in an enterprise like science that is concerned with providing explanations to events and happenings occurring within the natural world. It is on the basis of this perceived importance that students are encouraged to develop skills in scientific observation as part of the science instructional program.

This study investigated the influence of traditional African beliefs on achievement on observational tasks in biology. Data were collected from 319 pre-degree science students of Lagos State University using the Traditional Cosmology Test and the Test of Practical Skills. The results showed that students with a high level of belief in African traditional cosmology, superstitions, and taboos made significantly fewer correct observations ( $p < .001$ ) in comparison with those with a low level of belief. The possibility is strong, as interviews with a random selection of subjects from both groups on their responses to TPS show, that their traditional beliefs, superstitions, and taboos could have been a major factor responsible for this performance difference in observation. One should quickly add, however, that a number of other variables could be responsible for the observed difference since no water-tight control was established in the study.

As noted by inductivists, our minds are not blank slates; we interpret the sense data that enter our consciousness in terms of prior knowledge, beliefs, expectations, and previous experiences. This would appear to be why students have naive notions or preconceptions which they bring to science classes and which have the potential for hindering their making correct scientific observations and forming scientific concepts.

This study examined the proposition that observational skills, a key scientific process, can be influenced by students' beliefs in traditional African cosmology, beliefs, and superstitions. Data were collected which supported this proposition and endorsed the view that observation is not entirely theory-independent. This finding merits confirmation or refutation by more rigorously controlled studies and is worth noting by curriculum developers and users of inquiry-based programs in science.

THE EFFECT OF ANIMAL DISSECTIONS ON STUDENT  
ACQUISITION OF KNOWLEDGE OF AND ATTITUDES  
TOWARD THE ANIMALS DISSECTED

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A conflict exists over the use of animals in the classroom. One aspect of this use involves the dissection of animals. Animal protection advocates report that dissections constitute abuse of the animals dissected. The advocates state that what is learned by dissection could be more effectively learned by other methods. They claim that dissections result in students being more insensitive to animals. Science educators state that dissections do not constitute abuse; they are educationally justified. They claim that dissections actually help students to better understand and appreciate the animals.

The purpose of this study was to investigate how animal dissections affect student attitudes toward and the learning of information about the animals dissected. A comparison was made of the knowledge gained and the attitudes influenced by dissection with that gained and influenced by a lecture presentation.

The sample population for the study consisted of 350 students enrolled in biology classes in five high schools in a large, metropolitan school district. Seven biology teachers were involved. The classes were randomly assigned to two groups. Parallel instruction with similar objectives was provided both groups. One group received a lecture on frog structure, function, and adaptation while the other group dissected the frog to learn about structure, function, and adaptation. Pretests and posttests were used to detect differences in knowledge acquisition and attitudes. The pretest and a standardized test were used as covariates to adjust for initial differences. The influences of gender, race, and school type were also studied.

Data analysis revealed several significant findings. Students who were taught by lecture experienced greater gain in achievement than did the students who dissected the frog. However, there was no significant difference in achievement between minority students who dissected the frog and those receiving the lecture. Students who attended neighborhood schools expressed more positive beliefs about frogs with dissection instruction, but non-neighborhood school students indicated more positive beliefs with the the lecture approach. No significance was found concerning feelings toward frogs between the two treatment groups.

DETERMINANTS OF PHYSICAL SCIENCE TEACHERS' INTENTIONS  
TO USE INVESTIGATIVE TEACHING METHODS: A TEST  
OF THE THEORY OF REASONED ACTION

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The purpose of this study was to explore the utility of the Theory of Reasoned Action for understanding and predicting science teaching behavior. In particular, the study investigated the cognitive foundations and social support for physical science teachers' decision to engage in a specific teaching behavior, using investigative methods to teach physical science in a year long, general education, high school course consisting of one semester each of introduction to physics and introduction to chemistry.

Four constructs are central to the Theory of Reasoned Action: behavior (B), behavioral intention (I), attitude toward the behavior ( $A_B$ ), and subjective norm (SN). These constructs are functionally related through the equation

$$B \quad I \quad (A_B + SN) = w_1 A_B + w_2 SN$$

where  $w_1$  and  $w_2$  are respectively the relative weights or contributions attitude and subjective norm make to the prediction of behavioral intention and subsequently behavior. Attitude is determined by the perceived consequences of performing the behavior of interest (behavioral belief,  $b_j$ ), each consequence weighted by an evaluation of the outcome (outcome evaluation,  $e_j$ ) and summed over all outcomes. The determinants of attitude toward the behavior are described by the equation,

$$A_B = \sum_j b_j e_j.$$

Subjective norm has two determinants. Beliefs that other persons expect an individual to perform a behavior (normative belief,  $n_k$ ) are weighted by the individual's motivation to comply ( $m_k$ ) with the expectations of other persons, summed over all referents. The determinants of subjective norm are described by the equation,

$$SN = \sum_k n_k m_k.$$

Teachers participating in the study were enrolled in one of two courses developed for high school teachers of physical science. The courses were offered as part of the Summer Institute in Science, an EESA, Title II program funded by the Texas Higher Education Coordinating Board. Behavioral intention, attitude toward the behavior (and its determinants, behavioral beliefs and outcome evaluations), and subjective norm (and its determinants, normative beliefs and motivations to comply) were determined using the method

described by Ajzen and Fishbein. The functional dependence of behavioral intention on attitude and subjective norm was examined using regression techniques.

Fifteen salient beliefs and six personal referents were identified. Beliefs were examined to arrive at the primary determinants of attitude toward the behavior using stepwise multiple regression techniques. Personal referents were likewise examined to arrive at primary determinants of subjective norm. Results of regression analyses revealed that teachers' intentions to use investigative methods to teach physical science, the behavior of interest, were dependent upon attitude toward the behavior, not subjective norm.

Intent to use investigative methods to teach physical science appears to be the result of a teacher's personal decision to do so, without regard to social pressures.

Session D2.3: Contributed Papers

SUMMARY OF SCIENCE EDUCATION RESEARCH  
IN THE CARIBBEAN 1970-1987

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Research on science education in the Caribbean which has been completed and published between 1970-1987 in the form of doctoral or masters theses, published papers, conference/seminar papers, and university-based mimeograph research material was examined, synthesized, and organized around the following themes:

- Agriculture Education
- Assessment in Science Education
- Cognitive Development/Concept Attainment
- Curriculum Development/Implementation/Evaluation
- Environmental Education
- Science Achievement/Orientation
- Science Attitudes
- Nutrition/Health Education
- Science Education/Teaching
- Science Teacher Education
- Scientific Literacy

Over 300 papers from 17 islands were reviewed and discussed in terms of implications and future directions. A listing of research which is currently in progress, the personnel engaged in such research, statistics of school populations, and science curricula are also provided.

## STUDYING SCIENCE INFORMATION USING METACOGNITIVE KNOWLEDGE AND EXPERIENCES

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Students who have sophisticated metacognitive knowledge and constructive metacognitive experiences are competent students of school-presented information and are likely to comprehend important ideas from science textbooks. What is needed is a comprehensive research program aimed at determining how students, who study from science texts and other sources, efficiently monitor and foster their own comprehension of critical information. In addition, we need to determine what interventions work best for students with varying aptitudes under varying conditions of science learning. This theoretical paper develops a metacognitive framework useful in establishing researchable questions focusing on students' studying of science materials and describes methodologies suited to evaluate such questions.

Schumacher has used metacognitive theory as a basis for interpreting student studying and has generated a framework helpful in the production of a four-component model. A modification of his model includes student's: (1) multiple cognitive and affective goals; (2) metacognitive knowledge or a "sensitivity" to how studying methods work best under varying conditions; (3) metacognitive experiences or acquired feelings and realizations that students have acquired about using different methods under varying conditions; and (4) actual implementation of specific methods under specific conditions. This modified conceptualization is based on theoretical work done mainly by John Flavell, the developmental psychologist, and Brown and Baker, the reading specialists.

Hypotheses derived from this metacognitive model are meaningful in terms of teachers' concerns for their students' studying of science information. For example, science texts are full of dense prose, complex concepts, and unfamiliar words. Students' tasks typically are to orchestrate their cognitive processes and structures toward the difficult and complicated goal of focusing on relevant critical knowledge, while restructuring this knowledge in terms of their own background knowledge and teachers' critical task. Unfortunately, students receive little such direct instruction on how to study past the fourth grade, perhaps because so little is known about this difficult kind of academic thinking process.

Here is a sampling of research questions derived from a general metacognitive perspective and of particular relevance to science education. First, what are the differences between the way expert and novice students study science? Second, what intervention before, during, and after the studying act can direct and foster students'

proper conception of poorly or misunderstood concepts. Third, how should criterial tasks be described to students so that they can increase their changes of comprehension rather than mere memorization of conceptual definitions? Fourth, how can teachers increase students' sensitivity to knowledge about studying methods resulting in focused attention on critical ideas, their subordinate ideas, and enough details to acquire the critical science concepts? Fifth, what experiences can teachers provide students so that studying is a more defined, systematic, and efficient process of acquiring knowledge? Sixth, how can students be taught to monitor their own studying actions, signaling to themselves when there is a breakdown in the learning process, and implementing "fix-up" studying strategies. Seventh, what are the studying methods used before and after class discussions, laboratory work, and field settings? Eighth, what can teachers do to facilitate students' studying of unifying interrelated principles such as the scientific method, inquiry processes, structure-function relationships, and the ethics and technology of science?

#### FROM SHORT- TO LONG-TERM: IN SEARCH OF LONGITUDINAL STUDIES IN SCIENCE EDUCATION

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Schools are thought to prepare students for the future. The long-term outcomes of schooling are expected to be produced gradually, by cumulative effects of educational experiences. The cumulative and long-term nature of education, however, does not seem to have a high priority in the agenda of educational researchers, including researchers in science education. In spite of the fact that the desirability of longitudinal studies is an undisputed issue, such studies are scarce. The result is insufficient research-based knowledge on the long-term processes involved with, and outcomes of, school science teaching and learning. For example, there is not much longitudinal data on long-term retention of learning and conceptual development, on effects of curriculum innovations in terms of their long-term outcomes, or on the long-term impact of training programs and professional development of science teachers. When research-based conclusions have to be drawn in regard to these or to other long-term issues in science education, one usually has to rely on data derived from cross-sectional rather than from longitudinal studies or to extrapolate short-term data.

This paper makes various conceptual and methodological points from a review of studies that attended to long-term perspectives of science education. The review covers primarily empirical work published in major research journals in science education over the last 25 years. The focus is on "true" longitudinal studies, that is, studies that adopted a longitudinal design and followed the same subjects over time, beyond the boundaries of a single school year. Reference is made also to studies with other research designs, e.g., cross-sectional, retrospective, "mixed" or "patched-up" designs, all of which aimed at exploring changes over the long-term.

Session E2.3: Special Session

AWARDS PAPERS

Each year NARST members who have presented a paper at the previous year's NARST meeting are invited to submit copies of their paper for consideration for the NARST Outstanding Paper Award or the Practical Applications of Research Award.

Also, each year, the JRST Awards Committee reviews all of the papers published in the previous year's volume of the Journal of Research in Science Teaching and selects the outstanding published article.

The authors of the JRST award and of the NARST Outstanding Paper award will present their papers at this session.

Session F2.3: Informal Discussion

"AN HOUR WITH..."

The President  
of the  
National Association for  
Research in Science Teaching

Linda DeTure

This session provides NARST members with an opportunity to talk informally with the NARST president about matters concerning the organization.

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Session A2.4: Symposium

TEACHERS AS RESEARCHERS: COLLABORATIVE ENDEAVORS DESIGNED  
TO IMPROVE SCIENCE TEACHING THROUGH RESEARCH

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Science education researchers, and NARST members in particular, have always espoused the improvement of science teaching through research. Traditional research endeavors to improve science teaching have been based upon a linear model. This model begins with project development and concludes with the reporting and dissemination of the findings at AERA or NARST meetings. On occasion, researchers have informed classroom teachers of "What Research Says..."

This linear model has failed to result in widespread implementation of research findings. Why is this so? Some would argue that we simply have failed to make research findings accessible to teachers. For example, have you ever seen the Journal of Research in Science Teaching prominently displayed on any teacher's desk? Unfortunately, accessibility may only be part of the answer. We would like to offer another perspective: that is, science education research topics have often been of interest to the researcher, not the classroom teacher. Further, the traditional research model has prohibited active involvement on the part of classroom teachers.

This symposium will synthesize collaborative research initiatives with teachers being active participants in the process. This session will offer NARST members the opportunity to contemplate the role of research as it relates to classroom practice. The emergence of science teachers as researchers in schools is an exciting phenomenon. The collaborative models presented in this symposium should serve as an impetus for establishing additional projects, as well as a stimulus to positively effect change in the process of schooling through collaborative efforts.

SCIENCE TEACHER EDUCATION: WHAT DO WE KNOW?

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We have considerable information about science teacher preparation in the United States, including data as early as 1787, the RJSES report of 1968, a variety of surveys of science teacher education between 1960 and 1985, Druva's meta-analysis of research on science teacher education, and the Guyton and Antonelli Surveys of 1987. But, a considerable number of issues in science teacher education remain. Concern exists now over who should become a science teacher. Equally important to many is how science teaching can attract more high quality candidates and candidates who chose teaching ahead of other fields.

Alongside this major issue lie many others: Should we prepare teachers of science disciplines or teachers of broad-field science? What is the role of university science courses in teacher preparation? Some are focusing on methodology in questioning the relative need for science courses versus practical experiences and methodology courses. Looking strictly at teacher education, many are raising concerns about the nature of an effective methods course, sometimes decrying the lack of rigor and a seeming lack of purpose in many methods experiences. Although everyone is calling for more clinical experiences, we are still at issue over the proper role and placement of such experiences and what exactly should happen in them.

Many promising practices shed light on these issues. New NSF initiatives such as the Experimental Centers for Preparing Middle School Teachers and the Teacher Enhancement awards for improving science teacher education should provide much information. In addition, NSTA's Search for Excellence in Science Education in Teacher Education at the elementary, secondary, and continuing education levels has provided many examples of actual teacher education programs that are considerably different than the norm. When we add to this the ERIC study of promising practices and Tamir's review of international needs in science education, we find we do have considerable data on which to base an evolution of teacher education. Some ideas and reports are tied to general reform efforts and will require long-range study, scholarly exchange, and persistent communication. Unfortunately, science teacher education often lacks these attributes. This panel will address many of these issues, pointing out history, issues, promising practices, needs, and gaps to be filled.

Session C2.4: Special Session

ANECDOTAL HISTORY OF NARST

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The National Association for Research in Science Teaching is one of the oldest, most respected organizations in the education profession. It has a long and influential history. Jacobson, reporting at the 1977 NARST meeting, wrote:

In this history, there are lofty aims and important accomplishments, exciting programs and lively discussions, long hours of committee work and important changes in policy, reports of significant research and illuminating analyses of research, penetrating criticisms and bruised egos, long nurtured friendships and much cooperative work, widespread influence upon science learning and instruction but not as much as we would like, survival of crises and the glow of good times - it is a long and fascinating history. It is a history that should be studied for there is much to be learned.

Writing that history is a most difficult task. Few written records exist, possibly because the concept of history is difficult to apply to an organization whose founders are still living. Now the founding members of NARST are nearly all deceased, and most of the second generation (those trained by the founders) are in or about to enter retirement. Without written documents, the available historical information is mostly in the memories of current members and available only by oral history methods.

The authors of this anecdotal history are currently collecting recollections of NARST members who have contributed significantly to it. This list of contributors is a roster of prestigious, influential scholars and teachers whose lives have been dedicated to scientific literacy through improved science education.

NARST was founded Monday, February 27, 1928 by sixteen science educators who met in the Colonial Club in Cambridge, Massachusetts. The list of charter members, however, includes thirty-two names.

From this beginning NARST grew to over 1200 members in the halcyon days of the 1960's. Present membership (Fall 1987) is about 700

regular members plus about forty student and emeritus members. Of these, about 100 are non-U.S. members with about 40 in Canada and 60 in other countries, chiefly Australia and Israel. This international influence continues to grow steadily.

NARST edits the Journal for Research in Science Teaching, one of the best journals in its field. Its present circulation is about 2500. It can be found in all major academic libraries world-wide.

NARST and its members cooperate with, and work through, many other professional organizations such as the National Science Teachers Association, the Association for the Education of Teachers in Science, and the American Educational Research Association. NARST maintains close ties with science education organizations world-wide.

NARST is unique in its contributions from research to practice in a curricular field. It may be impossible to confidently document the impact of NARST and its members upon students, science, science education, and society. Connections and influences cannot be traced without a recorded history.

The authors believe that a history of NARST can open windows to the rich history of science education in the United States. We are attempting to document a factual history and to supplement this with an anecdotal history. We are convinced that this can be of great value to current NARST members and other researchers.

Key NARST members have been surveyed by questionnaire, and many have recorded oral interviews. This report will present intriguing and important anecdotes from the past.

Session D2.4: Contributed Papers

A FACTOR-ANALYTIC STUDY OF ATTITUDES OF GIFTED STUDENTS  
TOWARD SCIENCE AND SCHOOL

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A thirty-two item survey was developed from the 1983 International Science Study. A total of 299 gifted South Dakota seventh-tenth graders responded to the survey. A factor analysis of the data resulted in four factors. A principal factoring with Promax Rotation indicated differences between groups on factors dealing with Science as a national priority, Science in the classroom, challenges and anxieties of Science, and general dissatisfaction with school. Data are provided for normative purposes.

LEARNING TO THINK: A MAJOR FACTOR IN THE  
DECLINE IN ATTITUDE TOWARD SCIENCE

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This study investigates the decline in attitude toward science observed among students who participated in a year-long intervention to enhance scientific literacy. It has five scales: Motivation, Performance Based Self-concept, Reference Based Self-concept, Control, and Mastery. There was a decline in attitude from pre- to posttest scores on every scale except Reference Based Self-concept at the  $p < .00$  level. An evaluation instrument was developed to investigate factors known to influence attitude, as well as to assess the unique aspects of a problem solving literacy course responsible for the decline in attitude. This instrument included a Likert scale and open-ended questions. A subsample of 83 males and females was chosen from among the 250 freshmen in the intervention to respond to the evaluation instrument. Factors associated with a decline in attitude were linked to the difficulties students encountered in learning to

think. Activities and tests required the transfer and application of knowledge rather than memorization.

Although students enjoyed using the scientific equipment, they disliked having to analyze, draw inferences, or make hypotheses using the data from their experiments. In addition, despite every effort on the part of the developers, the students did not think there were any real-life applications for what they were learning. Students were not motivated due to the perceived lack of relevance. Their performance-based self-concept declined because of the perception of their inability to do science. Reference-based self-concept remained the same because the entire freshmen class was struggling with the same course material. Control declined because students attributed their success to factors other than their own efforts, especially in regard to the tests. Mastery declined because their old mastery skills, memorization and recall, were not suited to the nature of the course. On the other hand, most students expected to do well in the course and did not consider it too much work. They liked the teaching methods and felt that they were in a conducive learning environment. Most students also felt that they had a good teacher, despite his temper. They felt that he was well organized, well prepared, and extremely knowledgeable in science.

#### A CROSS-CULTURAL STUDY OF ATTITUDE TOWARD SCIENCE AND RELATED INFLUENTIAL FACTORS

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Success of Native American students in science and science-related careers has long been a dilemma for those educators in the population-at-large who seek to improve the representation of all minorities in fields of science and engineering. As a result of a preliminary study conducted to analyze the attitude of secondary Native American students on a South Dakota reservation, this study extended those findings by investigating the cross-cultural nature of attitude toward science and reservation-boundness with students of two races both on and off the reservation. Three populations (N=244) were identified. They were Native Americans in reservation schools, non-Native Americans in reservation schools, and non-Native Americans not in reservation schools.

Data from the attitude analyses, including overall and subscaled values, indicate three significantly different populations, two of which were operating on the same turf. Results indicate that even

though Native Americans and non-Native Americans on the reservation were significantly different in overall values, subscale scores indicate they were more like each other than like their non-reservation peers. Yet, further analysis of subscale values indicate non-Native Americans on the reservation interpreted instrument questions more like their non-reservation peers than like their Native American peers. Further analysis of cultural norms is suggested before linking attitude toward science with racial culture and reservation-boundness.

THE DETERMINANTS OF EIGHTH-GRADE STUDENTS' INTENTIONS  
TO ENROLL IN ELECTIVE SCIENCE COURSES  
IN HIGH SCHOOL

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Data were collected from eighth-grade students (N=174) to identify the determinants of their intentions to enroll in at least one elective science course (e.g., chemistry, physics) in high school. Fishbein and Ajzen's theory of reasoned action was the model used for this study. The model is designed to predict an individual's intention to perform a behavior. According to this model, the strength of one's intention to perform a behavior is a function of two factors: (1) beliefs about the consequence or outcomes of performing the behavior and the evaluations of those consequences (defined as attitude toward the behavior) and (2) subjective normative beliefs about what others think the individual should do and the individual's motivation to comply with those beliefs (defined as subjective norm). The effects of variables on the students' intentions to enroll in at least one elective science course in high school are mediated by the models' theoretical constructs. Therefore, variables external to the model will affect intention only to the extent that they influence attitude toward performing the behavior, subjective norm, or their relative weights. In order to test this hypothesis, in addition to others derived from the model, it was necessary to study the effects of several variables external to the model's theoretical constructs and to show how the theoretical constructs are related to the intentions of eighth-graders to enroll in at least one elective science course in high school. The choice of variables external to the model's theoretical constructs was based on previous studies undertaken to identify factors that affect students' decisions to enroll in science courses. Tested was the effect of subjects' gender, academic abilities, science grades, and attitudes toward science on the model's theoretical constructs.

The variables external to the model when considered independently were found to be unrelated to the three theoretical constructs. When using multiple regression analysis, a statistically significant relationship was found between attitude toward the behavior and science grade,

ability group, and attitude toward science. Attitude toward the behavior and subjective norm in combination were found to be statistically significant in their prediction of behavioral intention. Attitude toward the behavior was found to contribute more to the prediction of behavioral intention than subjective norm. Tests of association between attitude toward the behavior and the products of salient belief scores and between subjective norm and the products of salient referent scores were found to be statistically significant.

Because actual enrollment data were not obtained, the results of this study must be considered preliminary; however, it is important to note that this study provides support for several hypotheses derived from the Fishbein and Ajzen model. In doing so, it raises questions regarding the variables traditionally used as predictors of science course enrollment.

Session E2.4: Special Session

ANNUAL REVIEWS OF RESEARCH FOR 1984, 1985

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Each year NARST, in cooperation with the ERIC Clearinghouse for Science, Mathematics, and Environmental Education, commissions a comprehensive review of the research published during the preceding year. This review is published in Science Education. Tony Lawson and Jim Gallagher, who were authors for the two most recent reviews, will provide an overview of the research they analyzed in preparation for writing the annual review of research and comment on such matters as perceived trends or gaps in research topics.

Session F2.4: Contributed Papers

COGNITION APPLIED TO SCIENCE TEACHING:  
A STUDY OF A FOUR-WEEK SUMMER  
INSERVICE INSTITUTE

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This study evaluated a four-week summer inservice institute designed to improve the quality of secondary science education by providing science teachers with an overview of principles of learning and cognition and how they can be applied to science teaching, current research in science education, and a review of topics. The biological and physical sciences relevant to teaching science in ways that increase the relevance of the content and focus on its usefulness in an increasingly technical society. Thirty-four high school biological and physical science teachers, representing 13 cities and 17 school districts participated.

The institute activities involved an overview of topics in learning and cognition and in science (primarily from an STS curriculum). Specific cognitive topics covered included memory, problem solving, misconceptions in science, concept mapping, motivation, and individual differences. The science content focused on energy, ecosystems, evolution, natural resources, computers, and projections for the future. To integrate the cognitive and science aspects of the institute, participants prepared and presented teaching projects demonstrating cognitive principles.

The effects of the institute were evaluated by comparing pretest and posttest scores on knowledge tests of both cognitive and science content and information gathered via preliminary and post-institute surveys. Significant knowledge increases were observed, and overall, the survey results showed that the teachers found the information to be relevant, interesting, and appropriate for application to the classroom. Cognitive topics that were perceived as particularly interesting and useful were problem solving, concept mapping, and misconceptions in science. The most interesting and useful science information focused on natural resources, future projections, and an ecology field trip.

Virtually all (92%) of the teachers felt that the goals of the institute had been achieved to a moderate or great extent and that the program was especially effective in fostering a collegial relationship among the participants, aiding students in understanding their relationship to the environment, and in the application of

inquiry teaching and "hands on" activities to science education. When asked about specific activities they planned to directly incorporate into their teaching, the teachers mentioned concept mapping more frequently (41%) than any other aspect of the institute. Finally, 85% of the teachers indicated that they would recommend participation in the institute to a colleague.

AN INVESTIGATION OF THE EFFECTS OF INFUSING  
STS VIGNETTES INTO BIOLOGY INSTRUCTION  
ON LEARNER OUTCOMES IN STS

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Among the most popular techniques for infusing STS into extant science courses is the use of short STS vignettes as proposed by Brinckerhoff. The purpose of the study was to test the effects of infusing Brinckerhoff-type STS vignettes into a segment of high school general biology instruction, as compared to not doing so, on student awareness of current STS issues, the importance students assign to current STS issues, and actions taken by students on current STS issues. The study was carried out using four sections of Grades 9 and 10 biology taught by the same teacher using the Scott, Foresman textbook, Biology.

The non-equivalent control group design was employed such that two of the four sections of biology were randomly assigned to each of two treatments. The experimental treatment (two classes,  $n=27$  and  $n=22$ ) involved the oral interjection by the teacher of Brinckerhoff-type STS vignettes, relevant to the day's biological material, in the closing portion of biology lessons twice per week over a period of six school weeks. Once per chapter (every two weeks) the last portion of a class period was set aside for a discussion to explore the STS issues associated with the vignette delivered that day. Over the six-week period both the experimental and control classes ( $n=26$  and  $n=27$ ) completed their regular instructional activities on three chapters from the text: "Inheritance of Traits," "Gene and Chromosome Changes," and "The Viruses." The four classes were pretested and posttested with the STS Issues Questionnaire.

Analysis of covariance was completed, with pretest data on the respective dependent variable and the mean of three chapter biology tests given over the treatment period entered as covariates. This yielded non-significant ( $p<0.05$ ,  $df=1,97$ ) F values on each of four dimensions of student awareness of STS issues: total STS issues stated,  $F=0.12$ ; total STS issues stated and justified,  $F=0.62$ ; total new STS issues stated,  $F=0.78$ ; and total new STS issues stated and justified,  $F=0.45$ .

Pretest rankings by students of the three most critical STS issues facing mankind were maintained on the posttest. Analysis of covariance also yielded non-significant F values on STS actions taken in total and within six action categories, i.e., civil, consumer, legal, persuasive, physical, political, across the experimental and control groups.

It was concluded that the infusion of Brinckerhoff-type STS vignettes into high school general biology instruction did not result in greater student awareness of current STS issues, perceived importance assigned to current STS issues, or action on current STS issues over that resulting from biology instruction alone. The value of STS vignettes, at least as implemented and assessed in this study, is questioned. It is recommended that science teachers who wish to integrate STS into science courses not depend solely on STS vignettes.

ANCHORED INSTRUCTION: A GENERAL INSTRUCTIONAL MODEL  
WITH APPLICATIONS TO SCIENCE INSTRUCTION

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Most educators agree that it is important to help students learn to think for themselves and to solve problems. This emphasis on thinking has focused attention on processes involved in thinking rather than only on the contents of thought. Nevertheless, research demonstrates that knowledge of important content - knowledge of concepts, theories, and principles - empowers people to think effectively. Without appropriate knowledge, people's ability to think and solve problems is relatively weak.

An important challenge for educators is to teach relevant content in a way that facilitates thinking. The goal of the paper session will be to discuss some possible approaches for meeting this challenge. The discussion will focus on the concept of "anchored instruction." It will be argued that, although anchored instruction can be implemented without the use of technology, it becomes more powerful when used in conjunction with microcomputer technologies and videodiscs.

Anchored instruction is a model designed to help students develop useful knowledge rather than inert knowledge. At the heart of the model is an emphasis on the importance of creating an anchor or focus that enables students to identify and define problems and to pay attention to their own perception and comprehension of these problems.

They can then be introduced to information that is relevant to their anchored perceptions. The major goal of anchored instruction is to enable students to notice critical features of problem situations and to experience the changes in their perception and understanding of the anchor as they view the situation from new points of view.

Anchored instruction begins with a focal event or problem situation that provides an anchor for students' perceptions and comprehension. Ideally, the anchor will enable students to deal with a general goal that involves a variety of related subproblems and subgoals. Effective anchors should also help students notice the features of problem situations that make particular actions relevant.

Over the past three years several studies have been conducted by the authors using video-based anchors in instruction. Content domains have included mathematics and language arts as well as science. The studies will be summarized in the paper session. The results from all the studies indicated large differences in students' spontaneous use of information. Students who had simply read facts almost never mentioned specific information about the material they had read. Their answers tended to be quite general. However, students in other acquisition conditions that used an anchored instruction method made excellent use of the information they had just read. Overall, students who received information in the context of problem-solving were much more likely to remember what they read and to spontaneously use it as a basis for creating new sets of plans.

A final component of the session will be to discuss projects currently underway using the anchored instruction model and possible applications for science instruction.

DOES IT MAKE SENSE? SEQUENCING WITHIN INSTRUCTION  
IN SCIENCE CLASSES

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The objectives of this research paper are to (a) describe a study of logical organization and sequencing of instructional units in secondary school science as taught by a group of four teachers, (b) discuss the findings of interviews with the teachers regarding their understanding of the subject matter and its presentation, and (c) to create concept maps of the teacher's planning and presentations for analyzing the logical organization and sequence of instruction. It is the intent to use concept maps as a tool for understanding the teachers' lessons as presented but not necessarily as a tool for checking the students' understanding of the lesson.

There is a body of literature that is concerned with the use of concept maps as a tool to help students understand concepts and the relationships between key concepts. There is little, if any, evidence of the use of concept maps as a tool for understanding the logical sequencing and organization of a teacher's lesson. This is one of the focal points of this study.

Sub-issues of this study have added two additional areas of inquiry to the previous two of concept mapping and the logical sequencing of instruction. These two new areas are signal to noise ratio in the classroom and non-verbal communication by the teacher to the students. Non-verbal communication has an extensive literature available, as does signal to noise ratio. However, this paper proposes a new usage of the concept of signal and noise as it applies to the teachers' presentation of subject matter.

Results of this study show that teacher understanding of the subject matter is a necessary, but not sufficient, condition for clear student understanding of the concepts presented. As shown by the concept maps of the teachers' lessons, many teachers did not go through a logical and thoughtful presentation of the science concepts that they taught. The four teachers in this study, at least one of whom is an award-winning teacher, had no lack of understanding of the subject matter, but they did have some difficulty in presenting lessons that contain a logical flow.

A DISCOURSE ANALYSIS ON NEWTON'S SECOND LAW  
AS TAUGHT BY THREE EXPERIENCED  
HIGH SCHOOL PHYSICS TEACHERS

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The general question addressed in this study was to describe how high school physics teachers enact subject matter in their daily interaction with students, written materials, and physical equipment. In order to shed light on this question, three experienced teachers were observed for six consecutive months, mostly on a daily basis. Information about subject matter organization was gathered through fieldnotes, videotapes, documents, and interviews with teachers. For analysis purposes, it was decided to focus on the enactment of Newton's second law, a topic which is traditionally included in the theme on dynamics.

A microanalysis of the coherence in the teachers' discourse on Newton's second law reveals the existence of different patterns with respect to how teachers structure the relationships that can be derived from the concepts of acceleration ( $a$ ), force ( $F$ ), and mass ( $m$ ).

The findings have implications for student learning as well as for staff development. On the one hand, the study shows that similar groups of high school students are being delivered differently organized bodies of knowledge even in the case in which a similar textbook is being used. On the other hand, the work presents three case-studies of experienced teachers dealing with the teaching of a common topic such as Newton's second law. Information of this nature can be useful in the process of informing prospective physics teachers of how experienced teachers enact relevant topics of the school curriculum.

INTERPRETING TWO HIGH SCHOOL PHYSICS TEACHERS' PHILOSOPHICAL  
VIEWS ABOUT THE NATURE OF PHYSICS KNOWLEDGE: THEIR  
POSSIBLE ORIGINS AND INSTRUCTIONAL INFLUENCES

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This paper attempts to interpret the philosophical views about the nature of physics knowledge of two experienced high school physics teachers. The issue has come up as an important sidelight of a larger research work in which the researcher used interpretive methodology to study the two teachers' knowledge of the subject matter and the way they treated it in the classroom.

Interpretation of the teachers' philosophical views is carried out against the background of philosophical ideas of two groups of philosophers of science: the traditionalists, like Hempel, Nagel, Potter, and Lakatos, and the relativists, like Hanson, Polanyi, Kuhn, and Feyerabend.

Analysis of various sources of data, fieldnotes, interview transcripts, classroom discourse, and handouts reveal that each of these teachers articulated a wide range of philosophical views that may overlap with both the traditionalists and the relativists. One teacher viewed physics as an object and exact science that is ruled by structures of logic which were absolute and inviolable. He also saw what he termed as "continuity" in science, which implied the relevance and importance of both past and present scientific ideas. However, this teacher thought that we are not better off as far as our scientific ideas are concerned, for all that has happened is that we have had new theories with wider dimension.

The other teacher saw physical laws as "coming from nature." Nature, according to him, conceals "patterns" of behaviors whose discoveries are usually done through what he termed a spontaneous process on the part of scientists. This teacher, however, believed that scientists are not objective in their attempts to understand nature. However, communication among them may wash out this subjectivity.

The paper attempts to trace the sources of these ideas. College education, experience, and the textbook are cited as possible ones. It also examines possible influences of these ideas on their classroom treatment of the subject matter.

Session B3.1: Paper Set

INCORPORATING RECENT RESEARCH ON LEARNING  
INTO THE PROCESS OF SCIENCE  
CURRICULUM DEVELOPMENT

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This paper describes an approach to curriculum development based on recent research in children's learning, science teaching, and other fields. Specifically, the paper is based on developments in three areas:

- 1) History and philosophy of science. Recent scholarship in this area interprets science as a complex "conceptual ecology" shared by a community of scholars and used by them to describe, explain, predict, and control natural phenomena.
- 2) Research on children's learning and thinking about science. This research describes successful science learning as a process of conceptual change, a complex, active process in which students must construct for themselves the language, theories, skills, and values of science. The conceptual change process is driven by children's own need to describe, explain, predict, and control natural phenomena.
- 3) Cognitively-based research on the classroom teaching of science and other subjects. This research suggests a variety of teaching strategies that are useful for helping students through the complex process of conceptual change as they learn science. These teaching strategies can help students to become both active learners and disciplined thinkers about natural phenomena.

The paper suggests techniques that are feasible and technically conservative for the development of "tasks by conceptions charts," which represent the science curriculum in a way consistent with our current understanding of the nature of science and student learning. Also suggested are ways of using tasks by conceptions charts as a foundation for the development of effective instructional strategies and materials. It appears that for the first time the field of science education is developing a base of research findings and technical expertise sufficient for the development of conceptual-change-based science programs.

## ALTERNATIVE STUDENT CONCEPTIONS OF THE KINETIC MOLECULAR THEORY

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The purpose of this paper is to report on the development of a knowledge base on students' conceptions of molecules and their explanations of phenomena, including dissolving, expansion, and compression of gases, changes of states, etc., using the kinetic molecular theory. These conceptions have been classified into two categories: (1) those at the macroscopic level dealing with observable substances and phenomena and (2) those at the molecular level concerning molecules and their nature.

Two sources of data were used in this study: paper-and-pencil tests and clinical interviews. The sample for paper-and-pencil tests included four sixth-grade science classrooms. For the clinical interviews, 24 students from the same four classrooms were selected from three achievement levels. Both pencil-and-paper tests and clinical interviews were conducted before and after instruction of the unit on matter. Student responses were analyzed according to each of the coding systems developed for this study.

Four major findings of the study are reported in the paper. First, a list of common student misconceptions regarding matter and molecules was developed. Second, students were experiencing difficulties at both macroscopic and molecular levels, thereby interfering with their understanding and explanations of natural phenomena. Third, students had significant difficulties in giving explanations for natural phenomena. Finally, student responses were used as primary sources in revising existing curriculum materials.

The findings have significant implications for both teaching and curriculum development. First, teachers should understand that students' difficulties with kinetic molecular theory involve misconceptions at the macroscopic level (such as failure to understand evaporation of matter or the mixture of substances in the air), as well as difficulties in understanding molecules per se. Second, teachers should understand that developing molecular explanations for phenomena is a complex process that students will find difficult even if they have all the requisite knowledge. Finally, student learning difficulties should be identified and incorporated into the development of new curriculum materials.

USING A NEW MODEL OF CURRICULUM DEVELOPMENT THAT  
INCORPORATES RESEARCH FINDINGS TO WRITE  
A MATTER AND MOLECULAR TEACHING UNIT

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The purposes of this paper are (a) to describe how a new model of curriculum development was used to write a teaching unit on matter and molecules, (b) to contrast this new process with the process used in commercial textbooks, and (c) to discuss the advantages and disadvantages of each.

The description of the Matter and Molecules Unit will include: (1) an analysis of the kinetic molecular theory to determine the goal conceptions and concept mapping to determine the relationship among the concepts, (2) assessing students' prior knowledge of both the goal conceptions and the phenomena used to teach those conceptions, (3) using the data on students' prior knowledge to develop the Preconception - Goals Conception Chart and Task by Conception Chart, (4) assessing students' knowledge after they have studied the Models of Matter Unit, (5) using students' knowledge to estimate the relative difficulty of specific goal conceptions and tasks, and (6) using all this information together with other research findings on teaching and learning to develop the pilot Matter and Molecules teaching unit.

The first author of this paper is in a unique position to contrast the new process used in developing Matter and Molecules with the process used in developing the commercial version entitled Models of Matter because he was a co-author of both units. The contrasts will delineate the advantages and disadvantages of both processes.

Session C3.1: Contributed Papers

EXPERTISE, MENTAL REPRESENTATIONS, AND PROBLEM SOLVING SUCCESS:  
A STUDY OF THE CATEGORIZATIONS OF CLASSICAL GENETICS PROBLEMS  
BY BIOLOGY FACULTY, GENETIC COUNSELORS, AND STUDENTS

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Using problems in physics and computer programming, the mental representations used by experts and novices for organizing their knowledge of a discipline have been studied by observing the categorization schemes these subjects produce when presented with a diverse group of problems. In the present study, 7 biology faculty who teach genetics, 8 certified genetic counselors, and 21 students were asked to organize a set of 28 classical genetics problems based on how the person would solve them and then to describe their schemes in writing. Separately, subjects were categorized according to their success on four moderately difficult genetics problems.

Like the experts in previous studies, successful faculty and student subjects organized problems according to the "deep structure" of the problems, i.e., according to genetic concepts which might form the chapter headings in a standard genetics text. The organizational schemes of genetic counselors were not similar to those of the faculty subjects even though the counselors were also very successful problem solvers. Surprisingly, both the counselors and the students placed greater emphasis on the knowns and unknowns in the problems. In addition, the counselors emphasized the solution techniques to be used. Based on these findings, it does not appear that the mental schemes used by different sorts of experts in a given discipline to organize their knowledge of content and procedures in that discipline are necessarily designed along abstract/conceptual lines.

Therefore, there can be more than one kind of "expertise" within a discipline, i.e., experts who have organized their disciplinary knowledge in markedly different ways, all of which organizations may contribute to success. There is no "right" or "wrong" type of organizational scheme, though there are clearly organizations which facilitate the accomplishment of certain tasks/problems better than others. Having an organizational scheme for one's knowledge, however - even a scheme based on lines similar to those used by an expert - does not ensure problem-solving success. First, knowledge (both content and procedural) of appropriate type, breadth, and depth must be resident within that framework. Second, that information must be available, and the solver must be able to apply it in appropriate situations. The hypothesis is presented that the structure of the scheme by which a person organizes his/her knowledge about a discipline is most significantly determined first by the way the

learning environment is structured and by the goal(s) of the learner during the learning process, and then later by the way in which that knowledge is used.

Finally this paper considers the impact of these findings on the present understanding of problem solving and on science teaching.

LOGICAL AND CRITICAL THINKING ABILITIES OF SIXTH THROUGH  
TWELFTH GRADE STUDENTS AND FORMAL REASONING MODES  
AS PREDICTORS OF CRITICAL THINKING ABILITIES  
AND ACADEMIC ACHIEVEMENT

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The purposes of this descriptive-predictive study were to investigate the logical and critical thinking abilities of a convenience sample of sixth through twelfth grade students (N=182) and to determine whether logical thinking processes are predictors of critical thinking abilities and academic achievement. The instruments administered in this study are as follows: (a) the Group Assessment of Logical Thinking (GALT), (b) the Watson-Glaser Critical Thinking Appraisal, (c) the Ross Test of Higher Cognitive Abilities, (d) the SKA, and (e) the MAT-6. (The authors of the instruments have established the necessary validities and reliabilities on the instruments.) The GALT was administered to the total sample during September 1986 and the other instruments were administered during May 1987. The percentages per reasoning level for the total sample are 9% formal, 18% transitional, and 73% concrete. On both the Ross and the Watson-Glaser, the students in this study fell below the mean scores of the norm groups in all subtests and the total score. Although significant gender differences were not found for the total scores on the GALT, Ross, and Watson-Glaser, significant gender differences were found for individual modes and subtests. The five formal reasoning modes on the GALT were not predictors of critical thinking as measured by the Ross, but the modes proportionality and controlling variables on the GALT were significant predictors of critical thinking abilities as measured by the Watson-Glaser. Also, the formal operational modes on the GALT were significant predictors of academic achievement. The results of this study indicate that a significant percentage of students in grades six through twelve are neither logical nor critical thinkers, and yet the complexity of the twenty-first century demands these abilities.

EFFECT OF INTENSIVE INSTRUCTION IN CUE ATTENDANCE  
ON BASIC PROBLEM SOLVING SKILLS OF PRESERVICE  
SCIENCE METHODS STUDENTS

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Effective teachers of science need to implement strategies that incorporate scientific problem solving. Unfortunately, because many teachers have inadequate problem solving skills of their own, they tend to teach very structured confirmation-type lessons.

Intensive instruction in cue attendance has been identified as a possible technique for improving cue attendance, hypothesis generation, information search, research design, and in general, problem solving performance (particularly when a media production presenting complex and surprising stimuli is employed in the intensive instruction). Intensive instruction is defined as the process by which subjects are instructed to a high and difficult criterion level in hypothesis generation or cue attendance. Subjects are instructed to view a discrepant event scientific phenomenon and asked (a) to describe 75 relevant details (cue attendance) or (b) to generate five acceptable hypotheses to explain the observations made about the natural phenomenon.

This experimental study explored the use of intensive instruction in cue attendance as an instructional technique for improving the problem solving skills of preservice college students. The results indicated that the 23 students who were intensively instructed improved their abilities to solve problems in both the clinical and classroom setting over the control group which received no formal intensive instruction. In both instances the experimental treatment group subjects performed significantly better on the following dependent variables when compared to the control group: (1) identifying relevant details in a scientific problem, (2) asking a more diverse set of questions about the problem, (3) generating a more diverse and higher quality of hypotheses, and (4) having a higher quality of the designed tests of the hypotheses.

The results provide additional evidence that training preservice science methods students to become more critical observers of relevant details relates directly to the development of more successful strategies for the solution of science problems. It is hypothesized that the intensive instruction in cue attendance requires students to develop a strategy to systematically identify, categorize, and interrelate the variables influencing a scientific phenomenon. This in turn leads to an improved capability to relate different classes of cause and effect variables in formulating questions, developing hypotheses, and proposing scientific tests for each of the hypotheses.

CONTEXTS OF CLASSROOM CHEMISTRY: THE CRITICAL ROLE OF BELIEFS  
IN DETERMINING STRATEGIES FOR PROBLEM SOLVING

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Student beliefs, or conceptions of the nature of chemistry, are critical in establishing the student's context of classroom chemistry. These beliefs include conceptions of sources of chemical knowledge; the role of the teacher; the role of the student; the nature of chemistry problems; how to solve chemistry problems; the role of authority in chemistry; the role of creativity in chemistry; the role of algorithms; one's ability to do chemistry; how to study chemistry; and what it means to "understand" chemistry.

This study examined the relationship among beliefs, goals, context, and problem solving for science and engineering students enrolled in a general chemistry course. The study utilized traditional and non-traditional tasks in a variety of chemistry and non-chemistry contexts to examine the ways in which student beliefs limited the concepts and strategies seen as relevant and useful in solving the task. The ways in which students' beliefs about their ability to do the tasks and how the fairness, or relevance, of non-traditional tasks is related to both the students' persistence at these tasks and commitment to their understandings are also examined.

The model for the influence of belief discussed in the study is examined in relation to Skemp's discussion of relational and instrumental learning and to descriptions of epistemological development described by Perry and by Belenky, Clinchy, Goldberger, and Tarule. Excerpts from transcripts of clinical interviews will be used to illustrate findings such as (1) students may have a very different epistemological perspective of chemistry (or science) than of other disciplines; (2) students who view chemistry as a creative discipline and chemical knowledge as created are less likely to rely upon explicitly taught facts and algorithms and more upon general principles and problem solving strategies; (3) even when they have demonstrated sufficient conceptual knowledge and problem solving skills, students can often solve tasks in non-chemistry contexts but cannot solve analogous tasks in chemistry contexts (and visa versa) because strategies and facts are viewed as relevant only within a very specific context; (4) instrumental learners or received knowers often do not apply heuristic or metacognitive strategies when solving problems because they do not see such strategies as relevant to solving algorithmic tasks - the only tasks they perceive to be fair chemistry problems; and (5) relational learners may revert to instrumental understanding in order to survive in classroom chemistry.

Session D3.1: Contributed Papers

A COMPARISON OF THE EFFECTIVENESS OF DEMONSTRATIONS,  
VERBAL STATEMENTS, AND HANDS-ON EXPERIENCES ON  
CORRECTING A MISCONCEPTION OF FIRST GRADERS  
REGARDING MAGNETS

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The purpose of this study was to compare the relative effectiveness of five instructional interventions which were designed to correct a size-related physical science misconception in a group of first graders. The particular misconception chosen for the study is the belief that larger magnets are always of greater strength than smaller magnets. These interventions consisted of: (a) a demonstration lesson, (b) a hands-on lesson, (c) a verbal statements lesson, (d) a demonstration-plus-verbal statements lesson, and (e) a hands-on-plus-verbal statements lesson.

Subjects were tested three days before the treatment, one day after treatment to determine change of knowledge effect, then six weeks after treatment as a check for knowledge retention.

Six subjects were randomly chosen from each treatment group to be interviewed prior to the instruction, using a format based upon that used by Osborne and Freyberg, and on two occasions (one day, six weeks) after the instruction.

It was hypothesized that a demonstration treatment would result in the highest frequency of students who received a score of 100% on four misconception-related items on the posttest. It was also hypothesized that the demonstration treatment would result in the greatest retention.

Analysis of both test scores and interview data indicated that, although there is strong support for the corrective properties of a demonstration which directly confronts the misconception that a necessary direct relationship exists between magnetic strength and magnet size, a demonstration alone is not more effective than all of the remaining treatments in achieving change of knowledge or retention. Therefore, there is a lack of support for both research hypotheses.

Both treatments containing demonstrations, however, were more effective in achieving correction of the size-related misconception

and retention of the corrected concept than the treatments consisting of a hands-on treatment alone and verbal statements alone. This effectiveness of treatments containing demonstrations was further supported by the analysis of interview data. Greater drops in percentages of students who chose misconception-related responses were indicated for the demonstration treatments than for the non-demonstration treatments.

The results of this study appear to indicate that demonstrations that are especially designed to correct size-related physical science misconceptions in young children may serve a useful purpose in elementary science teaching by serving as instructional cores. Other, related activities based upon the corrected science concept could be developed by teachers as reinforcement to the content of the demonstrations.

#### MISCONCEPTIONS OF NINTH-GRADERS SURROUNDING GRAPH CONSTRUCTION SKILLS OF SCIENCE DATA

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The purpose of this study was to observe the development of graph construction skills of a self-contained class of thirty ninth-graders in a large urban high school through a school year. The literature review and early work in the classroom indicated that the students had several misconceptions about the construction of scaled axes.

It had been suggested in the literature that graph construction and interpretation errors could be interpreted in terms of student logical operational reasoning levels. The author observed the use of graphs by students and teachers over a period of ten months and tested the students' graphing and logical reasoning skills with the following instruments: (1) "The Test of Graphing Skills" (TOGS), (2) a series of exercises in which the students were asked to graph a set of data points on a blank sheet of paper; and (3) "The Group Assessment of Logical Thinking" (GALT).

Patterns of graph construction errors were interpreted in terms of categories based on Piagetian operational reasoning levels. However, the lack of correlation of both the TOGS and Wavering scores with the GALT scores indicated that operational reasoning levels were not the best framework within which to interpret the data. The data were re-analyzed in terms of Novak's model of concept mapping. A conceptual framework of specific relational understandings that students need to incorporate into their knowledge base of graph construction skills was developed.

Suggestions for future research and teacher education, especially in terms of use of computer software graphing utilities, were made.

A LONGITUDINAL CLASSROOM STUDY OF SOME MECHANICS CONCEPTS  
AND CONCEPTUAL CHANGE

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Although a number of factors may be responsible for the perceived difficulty of learning physics, the broad focus of this study was on the role students' existing conceptions play in the process of constructing and understanding physics concepts. The study derives from the alternative conceptions literature. In particular, it was concerned with identifying and representing students' existing conception, investigating some aspects of the process of conceptual change in classroom learning, and considering any relationships between these two aspects of learning.

The study was a naturalistic one, conducted over a number of years in the school in which one of the authors teaches physics. The content on which the study focused is mechanics, with particular emphasis on the concept of gravity. The study has two distinct phases. Phase One was a quasi-longitudinal probing of students' conceptions at various levels of high school, both before and after experiencing conventional instruction in either science or physics courses. Phase Two examined conceptual change in high school physics students experiencing instruction which attempted to reflect constructivist views of learning. Student perceptions of the causes of any conceptual change they underwent were also probed. Data from Phase Two allow inference about the role of existing conceptions in the genuine acceptance of new epistemological commitments.

Session E3.1: Contributed Papers

A COMPARISON OF THE INTEGRATED SCIENCE PROCESS SKILL DEVELOPMENT  
OF JAPANESE YOUTH AND AMERICAN YOUTH IN ACTIVITY-BASED  
AND READING-ORIENTED SCIENCE PROGRAMS

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The authors' purpose in this study was to compare the integrated science process skill development of a cohort of American youngsters who studied science for several years in an activity-based, materials-oriented program to a group of Japanese youth whose science program is also activity-based, and of a group of American youth whose science programs are textbook-based and reading-oriented. The means and standard deviations from Japanese and American textbook-based data on eighth-grade students were available from earlier research.

The authors administered an integrated science process skills test to 1,291 eighth-graders in a northwest suburban Chicago school district whose activity-based elementary science program is nationally recognized. Students (825) who had begun school in the district by the second grade were used for the comparison. Confidence intervals (99%) were calculated about the scale and total score means for all groups.

Results show that, for all scales and the total score, the confidence intervals of the American activity-based science group and the Japanese group are above and do not overlap the corresponding confidence intervals of the American textbook science group. For four test scales, the confidence intervals of the Japanese and American activity-based science groups overlap. For one scale and the total score, the Japanese confidence intervals are above and do not overlap the corresponding confidence intervals of the American activity-based science group.

Discussion focuses upon an explanation of the more favorable performance by the Japanese group on the total score and implications of the results for representing more clearly the crisis in science education.

## INTEGRATING PROCESS SKILLS INSTRUCTION INTO THE TRADITIONAL SCIENCE CURRICULUM

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Several studies have shown the importance of supplementing the traditional science curriculum with process skills instruction. But a science teacher wishing to add instruction in process skills is often faced with at least three problems:

- lack of text and lab materials which emphasize process skills;
- lack of time for accommodating new material in the curriculum;
- incompatibility of typical process skill instructional models with current teaching styles.

The purpose of this study was to investigate the possibility of teaching process skills through an approach which is primarily lecture-class discussion centered rather than lab-activity centered. One randomly selected tenth-grade biology class received the treatment along with regular content instruction over a two-week period, while a control class received only content instruction. The treatment consisted of presentation of 23 process skill lessons designed to cover eight basic and six integrated process skills as defined by the Science - A Process Approach curriculum. The lessons were of three types:

- overhead transparencies, requiring only a few minutes of class time each;
- worksheets, requiring 15 to 30 minutes in class or as homework;
- two labs requiring a class period each.

Students in both groups were posttested with the Middle Grades Integrated Process Skills Test (MIPT). The six-weeks grade for the grading period that included the treatment was used to test for possible negative effects of the treatment on biology content achievement. The previous six-weeks grade was used as a covariate in an Analysis of Covariance (ANCOVA) procedure. Results of the ANCOVA revealed that the treatment group scored significantly higher than the control group on the MIPT measure of process skills ability ( $p=.004$ ). No significant differences were found between the treatment and control groups in their biology achievement. Thus, students receiving the treatment did not suffer a decline in content achievement and gained in process skills ability. The experimental results clearly indicate that process skills can be successfully taught by the lecture-class discussion method.

DEVELOPING AND ASSESSING CHILDREN'S SCIENTIFIC OBSERVATION  
AND INFERENCEAL THINKING THROUGH A MUSEUM-SCHOOL PROGRAM

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An integrated museum-school program in Texas ecology was designed as a Tour-Lessons-Tests Model for use with fourth-grade children. The program integrates an interactive tour of an ecology exhibit with four classroom lessons on animal adaptation. The focal science processes are observing, inferring, and verifying.

Seven fourth-grade teachers in two schools comparable in SES were trained to use the program with their lower socio-economic Hispanic students. Fifty-two children experienced the program over six weeks. Ninety-one children experienced it in a two-week intensive format. Two classes totaling thirty-four children served as controls, one for each treatment timeframe.

Immediately prior to and following the program, all children were tested with an open-ended task in using skills of observing, making inferences, and finding supporting evidence for inferences. The pretest gave children a live oak leaf with attached gall to examine. A sweet gum seed pod was used for the posttest. The children were asked to write about the object.

Two coders were trained to apply a classification system to the children's writings. Interrater reliability was high for all scales: Descriptors, 0.986; Inferences, 0.881; Supporting Evidence, 0.873; Metaphors, 0.886. Blind coding of all pre- and posttests produced scores that were compared across two-week, six-week, and control groups. ANOVA's indicate that while there were no differences among the three groups on the Descriptor scale of the pretest, at the posttest the two-week group was significantly higher than the six-week group. From pre- to posttest only the two-week group showed a statistically significant change. On the Inference scale, the three groups did not differ at the pretest, but on the posttest the six-week mean was significantly higher than the means of the two-week and control groups. From pre- to posttest the six-week group improved significantly. No differences were found between the groups at the pretest on the Supporting Evidence scale. At the posttest the

six-week mean was significantly higher than those of the two-week or control groups. From pre- to posttest only the six-week group improved significantly. On the Metaphor scale no differences were found across groups on either test.

The findings support the value of integrated museum-school curriculum for developing children's observing and inferring skills. They also suggest that a short, intensive program can increase perceptiveness, but a longer program that provides time for reflection may be needed to increase children's inferring and the citation of verification for their inferences.

In addition to suggesting ways to use museum experiences for children's thinking in science education this study presents a method of evaluating growth in scientific observation and inferential thinking that teachers may apply to varied topics in the curriculum.

Session F3.1: Contributed Papers

AN INQUIRY INTO THE QUESTIONING BEHAVIOR OF  
YOUNG CHILDREN IN A SCIENCE SETTING

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This initial qualitative inquiry focused on two concerns: (1) the nature of children's questioning behavior in a science setting and (2) teacher behaviors/strategies which might tend to enhance children's questioning behavior. Over a six-month period the researchers engaged in regularly scheduled observations of the children and teacher, audiotaping and videotaping of science activities, conversations with children and teacher, and observations of the science setting in terms of materials regularly in the classroom and those materials introduced by the teacher and the children.

The following teacher strategies appear to merit further investigation:

- 1) presenting familiar and unfamiliar objects and/or materials to the child;
- 2) helping the child to focus, especially by asking the child to ask questions about the object or situation;
- 3) providing the child with a systematic method to learn scientific questioning techniques;
- 4) improving and expanding one's own (the teacher's) questioning behavior as a model for the child.

In a classroom in which science question asking was encouraged and perceived as a worthy behavior, the researchers noticed some patterns which merit further investigation:

- 1) over time the quantity of children's questions increases;
- 2) over time children's questions tend to become less generic and more reflective of science process;
- 3) over time children's questions reflect less dependence on the teacher and more self-starting behavior on the part of the student scientist;
- 4) over time children's questions reflect an increasing skill at asking questions which lead to productive action;
- 5) over time students are more likely to express an understanding of the importance of questioning in science.

SCIENCE AND MATHEMATICS EDUCATION LEADERSHIP PROGRAM:  
A CASE STUDY INVOLVING ELEMENTARY AND SECONDARY  
SCHOOL TEACHERS

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This program provided training in the areas of leadership, content updates in science and mathematics, and innovative teaching and learning strategies for elementary and secondary school teachers from public schools throughout Maine. The initial component of this program (1986-87) involved thirty-three secondary school science and math teachers in a three-week summer institute. The second component currently (1987-88) involves thirty-three elementary school teachers participating in eight day-long workshops conducted during the academic year. All of these teachers were nominated for this program by their superintendent and/or principal. Analysis of the secondary teacher data has been completed while the data for the elementary teachers is currently being collected and analyzed.

According to the Myers-Briggs Personality Indicator, the secondary school science and math teachers had leadership styles and personality traits similar to those of "100 of the best" educational executives in North America.

Based on their summer institute experiences, participants returned to their local school districts and conducted staff development workshops incorporating topics presented in the institute. These included content updates in nutrition, radiation, marine science, forestry, and molecular biology, as well as an interdisciplinary approach to science, math, and other subject areas, group dynamics, and computer applications of science and math.

Evaluation of this program was conducted by a team of researchers as part of the programmatic research effort in Science and Mathematics Education at the University of Maine. Eighty-five percent of the secondary teachers successfully completed the program which was determined when they conducted a staff development workshop and reported the results to the research team or were observed during the workshops. The high success rate of the first component of the SMELP program suggests the approach of identifying potential leaders rather than waiting for them to "fall out" of the usual staff development efforts.

The second component involving the elementary school teachers will be conducted Fall and Spring 1987-88. The data from the Myers-Briggs Indicator, effectiveness of the academic year workshops, and an evaluation of the staff development efforts of these teachers will be compared to their secondary colleagues in an attempt to identify effective staff development strategies.

THE GROUP DYNAMICS OF SPANISH HIGH SCHOOL  
PHYSICS AND CHEMISTRY TEACHERS  
REFLECTING ON THEIR ACTION

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The purpose of the study was to investigate the internal forces that shaped the dynamics of a group of high school physics and chemistry teachers reflecting on their action. It has not been until recently that educational researchers and practitioners have discovered the role reflection plays in the development of teaching expertise. Very little is known about the group dynamics of teachers reflecting on their practice. The study addressed the following questions: (a) Is there an evolution of the reflecting process of a group of physics and chemistry teachers? and (b) How can this development be explained?

Five physics and chemistry teachers from two public high schools from the area of Barcelona participated in the study. Two groups of teachers were formed in both high schools. All teachers had weekly meetings of approximately one and a half hours each. One group met 15 times, whereas the other group met 12 times, over a period of six months (January-July 1987). The teachers identified the problem they would like to confront in subsequent meetings.

The method and framework of analysis was drawn from Shulman and Schoen's framework, action-research processes, group dynamics theory, and interaction analysis.

The following teachers' factors have been identified, at the moment, as playing a crucial role in the development of a group of high school teachers reflecting on their practice: (a) pedagogical content knowledge structures, (b) openness to questioning, (c) persistence in solving problems, and (d) tolerance to uncertainty. The group dynamics established within each group had the following tentative phases of development: (a) problem definition, (b) role setting, (c) learning to reflect on one's own practice, (d) cohesiveness, and (e) dissemination.

Teachers' reflection on their action is not an easy activity. When reflection is done through interaction within a group, the process becomes long, complex, and needful of external support. Teachers' knowledge restructuring might take place if the group dynamics and personal characteristics of teachers are carefully considered. The two cases presented here contribute to the understanding of the interplay between science teachers' thinking and action. Such an understanding is necessary if science teacher educators want to imprint a dynamics of continuous change into schools.

Session A3.2: Symposium

A SYMPOSIUM ON THE GROUP ASSESSMENT OF  
LOGICAL THINKING (GALT) INSTRUMENT

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The Group Assessment of Logical Thinking (GALT) is a paper-and-pencil test designed to identify students' stages of cognitive development. Based on the work of Piaget, it has high concurrent validity with Piagetian interview protocols. Since its development in 1981 the test has been widely administered throughout the United States and in other countries. The symposium will bring together those involved in the development of GALT, researchers who have used the instrument in large sample studies, and discussants to examine both research findings and measurement aspects of the instrument. The widespread use of the GALT in the United States and its international acceptance provide a rationale for this timely evaluation of the instrument and the research findings it has generated.

Session B3.2: Contributed Papers

A TAXONOMY OF CURRICULAR DISCOURSE IN SCIENCE

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A secondary school chemistry curriculum project has been in existence for over a decade. During the course of its work the project group and those doing research within the context of this group have become convinced that a way of organizing and talking about science textbook discourse is required which reflects the nature and variety of contemporary science-technology-society (STS) knowledge. Such a scheme would need to incorporate a multiplicity of contemporary perspectives on science and science education and would need to yield data which permits curriculum developers to objectively describe and modify curricular text in directions which are perceived as desirable.

Science curricula are becoming more complex, both in their attempts to portray the societal and technological impacts of science and in attempts to educate a larger proportion of youth. The search for a taxonomic framework which incorporates the richness and complexity of contemporary STS and pedagogical knowledge about science teaching while at the same time retaining a disciplinary subject focus has resulted in a Taxonomy of Curricular Discourse.

The taxonomy represents an attempt to make epistemology accessible to teachers and learners through the language of the practical as distinct from the language of philosophy. The classification is grounded in the professional practice of a group of chemistry teachers who develop, try out in their classes, and revise chemistry curriculum. The approach used is conceptual analysis.

The taxonomy takes a multi-perspective view of science. The five theoretical perspectives which form the basis of sentence-by-sentence analysis of textbook discourse are: epistemology of science, normative perspectives, curriculum emphases, practical inquiry, and science-technology-society (STS) education. These perspectives provided criteria for testing the validity of the taxonomy which evolved in the course of analyzing and classifying six chapters of high school chemistry text.

The major findings of the research are epistemological. An epistemological triad of resultant knowledge, procedural knowledge,

and required action was discovered to be present in all science textual discourse. The triad conceptualizes the relationship among the "what," the "how," and the "action required" components of curricular discourse. From a normative perspective, ten knowledge forms were initially identified as being valued by various interest groups within chemistry. From a curriculum emphases perspective twenty-two knowledge forms are subsumed within the five curriculum emphases of science, technology, society, communication, and pedagogy. A definition of science-technology-society science education in terms of conceptual, descriptive, process, and epistemological knowledge forms is developed.

A research-practice dialectical relationship with the ongoing curriculum project was employed throughout. The data emerging from the analysis have guided subsequent curriculum writing as the teacher-curriculum developer group looked for ways to integrate the various aspects of the contemporary science and science teaching/learning enterprises in a way that makes sense to both teachers and learners. Epistemological harmony with teachers was sought by developing a language for explicitly introducing epistemology into classroom science teaching.

The Bloom Taxonomy of Educational Objectives provided educators with a set of conceptual categories and a language for talking about evaluation. The Taxonomy of Curricular Discourse is presented as a point of departure for the examination of the nature of curricular knowledge in science and its ongoing pedagogical purposes.

#### AUTHENTIC SCIENCE - JUST ANOTHER BUZZWORD?

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Influential documents such as A Nation at Risk or the Science Council of Canada Report #36 as well as numerous papers appearing in science education journals are challenging teachers and curriculum developers to present a "real" or "authentic" view of science. This paper looks at the term "authentic science" and its multiple meanings with respect to science education. In particular, three relevant denotations of authenticity are applied to eight facets of science. These facets include methodological and epistemological aspects of science,

personal, public, historical, societal, and technological dimensions of science as well as the aim of science. For each of the above facets of science, application of the term "authentic" is shown to be problematic in ways that seriously weaken the use of the term in science education.

Coupled with this is the problem of defining what is authentic for the student, the teacher, the curriculum developer, or whoever is to acquire an espoused view of "authentic science." This multiplicity of meaning suggests that "authentic science" may, in fact, become nothing more than a buzzword in science education. Such an outcome could delay and confuse the steps needed to address the current concerns about school science expressed by many.

The sheer diversity of contemporary science and science education suggests that a more open-ended view of science, such as one built on the notion of richness, may communicate the complexity of science more effectively to teachers and students. The analysis concludes with a discussion of how the notion of richness working through the idea of personal science can be used to develop ways of teaching that will help students respond as intelligently as possible to the complexity that characterizes contemporary science.

#### TEACHING THE BIOCHEMICAL ACTIVITY OF THE CELL USING META-PROCEDURAL REORGANIZATION

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The problem addressed in this research was: Is it possible to teach basic knowledge about the biochemical activity of the cell for eleventh-grade students in Jordan using informed meta-procedural reorganization for student's theory?

The objectives of the research were: (1) to obtain a detailed description of the qualitative differences in students prior to, during, and after instruction about the biochemical activity of the cell and (2) to assess the effectiveness of meta-procedural organization in featuring students' understanding that will allow them to explain phenomena in a logically coherent, scientific view.

Twenty eleventh-grade girls in a Jordanian high school were assigned to treatment and control groups. Students in both groups were pretested and posttested with an open-ended test designed by the author. The treatment group was given seven enriched lessons which stressed the logical-historical development in the biochemical activity of the cell, based on work by Carey which postulates that the kinds of conceptual change that characterized scientific revolution

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would be important also in students' meta-procedural reorganization of their theory. The control group continued in its regular classroom instruction.

Significant differences were found between experimental and control groups in the posttest using ANCOVA design analysis. However, primary analysis of tape recordings and homework for the three most verbal students in the experimental group provided a somewhat different picture. The primary analysis showed that some serious misconceptions persisted throughout the instruction. Even though these students changed in their wording of certain concepts, some fundamental understanding showed little change. For example, in the pretest two of the three students came with the naive ideas that the plant weight comes from the organic material in the soil and that planting cereal grains would enrich the soil. They changed their concept in the posttest to end up with the identical concept to the third student, mentioning that the weight of a plant comes from photosynthesis and that organic material burns in every cell to obtain energy. However, when pressed through class discussion, it was evident that the three students equated light with photosynthesis.

After detailed analysis for the whole group, it appeared that this method was more successful when students' naive theory is of a natural, spontaneous type such as is found in the history of science, i.e., the weight of a plant comes from soil or from water only. It appears to be more difficult for students to succeed when their misconception is related to misunderstanding of textbook words. For example, the textbook phrase, "plants store energy," was understood as "the weight of a plant comes from light." In another example, the textbook statement, "a plant makes its food by itself," was understood as "the weight of a plant comes from nothing but was absorbed at another time by the plant in the form of organic material." For some students, the general statements in the textbook merely compound misunderstanding and mask it with words that are empty of meaning but sound correct.

#### LEARNING IN AN INFORMAL SETTING AT THE ZOO

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The study was designed to investigate the outcomes of providing informal educational experiences to the public in a zoo setting. A special "Exotic Cat Show" was designed to make the audiences aware of the need to preserve the endangered species of large cats from extinction. The shows were presented to the general public by docents eight times per week during the summer months. A large sample of individuals, aged 7 through 80, completed a questionnaire at the end of each show consisting of 9 items. Data were collected over a three-week period in August 1987 at the Cincinnati Zoo. Data analysis indicated visitors' willingness to learn more about the cats and their support for the protection of exotic cats. Individuals are receptive to information if they are exposed to it in a favorable environment such as the informal setting of a zoo.

Session C3.2: Contributed Papers

TOOLS FOR TEACHING PROBLEM SOLVING: AN EVALUATION OF A  
MODELING AND SYSTEMS THINKING APPROACH

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During the summer of 1986 a group of 15 racially diverse students entering tenth and eleventh grades participated in an intensive four-week course taught by members of an NSF-funded project. The project's goals are to develop science and math curricula based on the principles of systems dynamics. The course was a test of materials intended to provide students with methods for problem solving by introducing them to modeling software and concepts of systems thinking. Students engaged in a study of levels and rates, causal-loop diagrams, feedback, exponential growth, exponential decay, goal-seeking behavior, s-shaped behavior, and oscillating behavior by modeling real-life problems. Some of the problems that students worked on dealt with population growth, bank balances, temperature cooling, capacitor discharging, city growth, and predator-prey relationships.

Nine boys and six girls volunteered to participate in the project. None of the students had any math beyond geometry, and pretest results showed a wide range of ability to deal with algebraic and numerical concepts. Evaluation of the course consisted of pre- and posttesting, observations, administration of a student background questionnaire, and interviews with students at the conclusion of the course.

During the course students demonstrated an increasing understanding of modeling concepts. Students actively discussed the difference between rates and levels and recognized that different problems shared the same underlying structure.

Results of tests administered to the group before and after the four-week class supported the observations of what students learned. Students improved the most on questions dealing with exponential growth and decay. A total of seven items on the test, which presented questions in several different formats, dealt with these concepts. Students improved substantially on all of these items.

Another set of items on the test that showed substantial gain involved graphing and graph interpretation other than exponential growth and decay graphs. Seven items tested a diversity of graphing skills, including matching a graph with data given in a table, choosing graphs that best represented the rates and levels in a described relationship, and choosing graphs that represented a depicted physical

situation. What makes the gain in this third set of questions particularly noteworthy is that many of the graphing skills tested by these questions were not explicitly taught during the course.

All questions in the categories described above showed more than a 30% gain in correct responses from the pretest to the posttest. The fact that students were able to answer questions that were not explicitly covered in the four-week course demonstrates that some transfer of skills, particularly in the area of graphing and graph interpretation, had taken place. However, more research is needed on how students learn modeling techniques, on how these skills enhance their understanding of math and science concepts, and on the extent of the transferability of skills involved in using modeling techniques.

#### PROBLEM SOLVING BEHAVIOR OF SUCCESSFUL AND UNSUCCESSFUL SUBJECTS LEADING TO A GENETICS PROBLEM SOLVING MODEL

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The study of Mendelian genetics is an integral part of the curriculum in introductory biology courses at secondary and post-secondary levels. Results from previous genetics learning studies and needs assessments demonstrated the need for more intensive research in biology education in general and genetics learning in particular. Problem solving behaviors and genetics concepts employed by experts and novices during interaction with a genetics computer simulation, "Catlab," were explored. Thirteen subjects investigated a common hypothesis on a specific genetic trait (coat patterns).

Successful subjects (two experts and two novices) exhibited the most complex patterns of problem solving sequences and used principally description problem solving sequences. The least successful subjects (five novices) exhibited more random approaches during problem solving than did other subjects. An intermediate group of less successful problem solvers (one expert and three novices) exhibited some of the problem solving sequences of successful subjects.

Successful problem solving in genetics appeared to include the use of description problem solving sequences and the use of specific genetics concepts. Verbalizing description problem solving sequences may have helped subjects in recognizing, analyzing, interpreting, and evaluating underlying patterns characteristic of inherited traits. The findings reported in this study may reflect situations where successful problem solvers can utilize a variety of approaches (pathways) and draw upon support structures of quantitative or qualitative problem solving sequences and general or specific genetics concepts to investigate hypotheses. A performance-based model for

genetics problem solving was formulated from conclusions from this study. The proposed model represented an attempt to integrate problem solving behavior sequences with the use of genetics concepts to examine and to predict successful or unsuccessful performances.

Further research is needed to elucidate the linkages and levels of variables influencing successful problem solving. Analyses of descriptive research studies, such as the one described here, can serve as important sources of information about cognitive and affective behaviors and computer-based education. Such studies can aid our understanding of how learners develop important scientific concepts and problem solving skills and strategies. In addition, these studies provide information for teachers to employ appropriate instructional strategies based on learning models.

#### STUDENTS' REFINEMENT OF KNOWLEDGE DURING THE DEVELOPMENT OF KNOWLEDGE BASES FOR EXPERT SYSTEMS

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Science education attempts to impart not only domain-specific knowledge but also domain-specific problem solving skill. In problem solving, declarative knowledge (concepts, principles) is needed to formulate an adequate problem representation, while procedural knowledge (rules, algorithms) is needed to execute appropriate problem-solving action. Instruction typically emphasizes either declarative or procedural knowledge but seldom aims at integrating the two in a way that emulates real scientific thinking. Cues inherent in the problem description (conditions, constraints) seem to control the selective retrieval and matching of declarative and procedural knowledge. Unfortunately, much of this conditional knowledge of when to use specific information, and why it is significant, is frequently left to the student to acquire through incidental experience. But if conditional knowledge is instantiated by thought processes inherent in analysis, synthesis, and evaluation, it can be taught directly.

Research is beginning to show how new computer technology can be exploited to help students gain more robust and informed views of science disciplines, while providing researchers with far more powerful tools to study how students learn. Novice knowledge engineering offers interesting insights into what students know, how they know what they know, and the relatedness of what they know. It compels students to think systematically, deeply, and productively about the intrinsic characteristics and relationships of a topic. Planning and formulating the knowledge base for an expert system leads students to focus explicitly on conditional knowledge, and in such a

way that they come to a clearer understanding of the content structure. The construction of a knowledge base (CKB) allows one to teach students domain-specific content together with its organization, thus facilitating an explicit emphasis on conditional knowledge. This helps students solve problems that resemble real-life problems more effectively.

This paper describes a descriptive evaluation of classroom knowledge engineering as an instructional strategy to teach domain-specific problem solving in classical mechanics. Results indicate that students not only acquired conditional knowledge but also integrated their knowledge leading to improved problem solving. Using expert system technology helped students structure their knowledge base coherently, concisely, and without redundant information. Aspects that they had learned rotely and did not understand, and therefore could not use, soon became evident to them, resulting in self-evaluation of the extent, adequacy, and appropriateness of their knowledge. This instructional strategy has the potential to increase fundamental understanding of science learning and to yield new views of teaching and learning.

#### EXPERT AND NOVICE PROBLEM-SOLVING PERFORMANCE IN GENETICS AND PHYSICS

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Research about problem solving in physics has produced models of expert and novice performance. Genetics provides problems to test these models. The purpose of this paper is to describe expert and novice problem-solving performance in genetics and make comparisons with physics problem-solving performance.

Three characteristics of domain-specific knowledge of experts solving textbook physics problems have been identified: (1) it is stored in large-scale functional units; (2) it includes procedural knowledge; and (3) it is used for problem representation. The strategic knowledge of experts includes problem re-description, solution synthesis, and solution assessment.

In this study seven experts (persons with a Ph.D. in genetics and experience in research and teaching), six advanced novices (volunteers taking an introductory university genetics course), and 20 beginning novices (high school students who had just completed the genetics

unit in introductory biology and been chosen by their teachers to represent a range of abilities) solved microcomputer-generated classical genetics problems while thinking aloud.

The program used was "Genetics Construction Kit" (GCK). This program provides a simulated laboratory environment in which users solve problems by inferring genotypic information from phenotypic data. The simulation begins with a display of field-collected organisms. Solvers make crosses until the inheritance pattern can be inferred. With GCK problems can be constructed with up to four traits, one of four inheritance patterns, and five modifiers. This customization makes the program flexible for use with individuals having diverse experience.

Transcripts of the think-aloud protocols and printouts of the computer-kept records of crosses provided the research data. The analysis consisted of six steps in which the raw data were converted to genetics principles, tabulated, and reduced to descriptions of performance.

Genetics experts store their knowledge in highly structured schema about inheritance patterns. These schema consist of content knowledge including abstract expression charts and procedural knowledge including complete, accurate sets of cross rules. Experts identify cues in the data, construct problem representations and access the appropriate schema, produce data to test hypotheses, and confirm their solution. Experts explain and predict data and generate family lines.

Advanced novices construct schema that are not as complete, accurate, or structured as experts. For example, their sets of cross rules are incomplete. They do not construct problem representations. They recognize data to justify the solution but are unable to produce such data. They only explain data and do not generate family lines.

Beginning novices do not appear to have schema but have their knowledge stored randomly. They approach a solution as if each cross were a separate problem, rely on only one cross rule, explain data when they are able, and ignore data they cannot explain. They do not generate family lines.

The description of the performance of experts and novices solving genetics problems confirms the model of problem solving from physics. Differences can be explained by differences between disciplines and between textbook and computer-generated problems. The paper concludes with prescriptions for instruction in genetics.

THE ECOLOGY OF AN ELEMENTARY SCIENCE CLASSROOM:  
TEACHERS AND RESEARCHERS AS CO-INVENTORS

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The National Science Foundation (NSF) has recently awarded grants to develop three elementary science curricula. Although the scope and focus of each program differs, there is a shared theme for each curriculum. Each curriculum is to teach children the concepts and processes of science through a constructivist philosophy. Teachers in elementary school, however, do not devote much time to teaching science, and when they do teach it, they rarely use a discovery, activity-based program. If this new generation of science curricula is to impact the teaching and learning of science in elementary schools, then it is important that we document the complexity of the elementary school science classroom. This information is necessary if we are to clearly articulate strategies that support teachers in developing a constructivist approach to teaching science.

This problem is addressed through a study of the classroom ecology. A multiple case study design was adapted such that researchers and teachers became co-inventors; that is, both of these groups shared in the development of research questions and the analysis of findings. Such a process was necessary to generate information that was both theoretically sound and practically useful. This paper focuses on data gathered during the first year of a four-year study of the context of elementary school science as part of the development of a K-6 curriculum. A case study design was used to uncover the complexity of the classroom milieu. The utility of the case study in uncovering the ecology of the elementary science curriculum is considered. Implementation strategies are then proposed in light of the case study findings.

THE EFFECTS OF ITEM FORMAT ON THE NATURE OF JUSTIFICATIONS  
TO MULTIPLE CHOICE ITEMS USED FOR DIAGNOSTIC PURPOSES

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Although individual interviews are very effective in uncovering students' preconceptions and misconceptions, they are time-consuming and their use in the classroom is not practical. The present study reports the use of justifications to multiple choice items as a means for uncovering students' conceptions, misconceptions, and reasoning patterns.

Three item formats were used: a regular multiple choice, a multiple choice item in which the correct answer is marked, and a correct statement. In the first case the students had to choose the best answer and justify their choice. In the second and third cases they had to explain why the presented answer is correct.

Fifteen hundred 12th-grade biology students in Israel responded each to one of three versions of a 20-item test in which each item focused on an important concept. Based on responses of 200 students, detailed category systems were developed. The responses of the whole sample were analyzed along these categories.

Significant differences were found between the responses to the three item formats, both in the frequency distributions of various categories and in the percentage of correct answers. Based on the findings, the use of justifications to multiple choice items is recommended for teachers, examiners, and researchers.

A CASE STUDY OF PRIOR KNOWLEDGE, LEARNING APPROACH, AND  
CONCEPTUAL CHANGE IN AN INTRODUCTORY COLLEGE  
CHEMISTRY TUTORIAL PROGRAM

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This study was a case study involving a small group of students enrolled in a tutorial program learning introductory college chemistry. The underlying theoretical framework of this investigation was a constructivist view of learning but more specifically based on

Ausubel's theory of meaningful learning and on a model of learning as a process of conceptual change developed by Posner et al. and further elaborated upon by Hewson.

The study questioned (a) whether tutorial students undergo qualitative changes in their knowledge (conceptual change), characterized and described by changes in conceptual status (intelligibility, plausibility, and fruitfulness of conceptions); (b) whether such changes are related to the learner's learning approach and to the nature (quality and quantity) of their prior knowledge; and (c) whether some students change their learning approach over time. Data were collected over a whole school semester, concentrating more completely on four knowledge domains, involving three different methods of data gathering: (1) tape recording of all tutorial sessions, (2) individual interviews, and (3) "teachbacks." The latter method consisted of having the subjects teach to the investigator a selected chemistry topic. Interpretations based on the "teachback" transcripts were substantiated by six independent judges.

The findings of this investigation were: (a) in fact students undergo qualitative changes in their knowledge, but some students more so than others; (b) these changes were related to the students' learning approach, i.e., positively related to the adoption of a meaningful learning set (a predisposition to learn meaningfully), and to the nature (quality and quantity) of their prior knowledge; and (c) evidence suggests that at least one of the subjects changed from essentially rote to a more meaningful learner. In addition, it is important to point out that this study has explored very extensively Ausubel's condition of adopting a meaningful learning set for meaningful learning to occur, on which parameter previous research is almost non-existent.

Session E3.2: Contributed Papers

ENRICHING ELEMENTARY SCIENCE INSTRUCTION THROUGH JOINT TRAINING  
OF INSERVICE TEACHERS, PRINCIPALS,  
AND INSTRUCTIONAL SUPERVISORS

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There is a need for improvement of science education in the United States. Existing curricula and instruction have been declared largely inadequate, and there is intense pressure for reform. Several major studies in the late 1970's indicated that the problem is especially severe within the field of elementary instruction. Although once a national priority, elementary science instruction now receives little emphasis in many schools. Consequently, many elementary students are deprived of an opportunity to build a sound science background for subsequent science studies. The purpose of this research was to illuminate and justify options for inservice teacher education programs to enrich the quality and quantity of science instruction in the elementary grades.

Philosophical assessment of the status of elementary science instruction generated an innovative concept of inservice teacher education that culminated in a quasi-experimental program for the enrichment of elementary science instruction in rural and small school systems in Tennessee. The study indicated that an effective program would require that both the instructional and administrative skills needed for reform be developed simultaneously within the existing structure of educational leadership. Further consideration indicated that such an objective should be more readily attainable through joint training of teams of elementary teachers, principals, and supervisors of instruction. Although conceived from the perspective of elementary science education, it is reasonable to conclude that this strategy for team leadership should be applicable to all levels of school science instruction and to many other subject areas.

This research demonstrated the practical benefits of philosophical research as an efficient method of gaining insight into new program options from a synthesis of prior research. In summary, analytical and speculative analysis of the issue of elementary science instruction provided an efficient overview of the problems involved and generated a new option for consideration in responding to an expressed teacher education need. Research of this nature should be equally applicable to other educational issues. Perhaps more important, this research approach provides a means to attain increased confidence in the efficacy of an option as philosophically

justifiable. This can be critically important to the maintenance of public credibility in an era of increasing educational accountability.

This research has provided a precedent for a team training program concept that promises to bridge the gap between school teachers and administrators that has been cited as the major deterrent to effective reforms in science education. Through such a program, each participating school system may gain a local team of educators with each member cognizant of both the instructional and administrative dimensions of educational program development. The resultant clearer channels of communication alone should help those school systems to overcome many hurdles in the quest for better science education.

### INFLUENCES OF CLASSROOM AND COMMUNITY ON YOUTHS' PERCEPTIONS OF SCIENCE

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The purpose of this study was to provide a qualitative, descriptive account of youths' understandings of science in grades 1-12 in a rural community. The study presented an overview of the science programs offered in the community's schools and related what children learned about science in classrooms to what they learned about science in other contexts. Much of the study was set in the community's classrooms, the place where formal transmission of knowledge about science mainly occurred, but the perspectives and influences of school and county administrators, parents, and other community members were also brought into the narrative.

The study employed a variety of data sources and methods of data collection. The methods utilized included participant observation, informal and formal interviewing, mapping, inventorying, and gathering documents. Triangulation of methods and sources was done to enhance reliability and validity of data. The constant comparative method was used for data analysis. This method involves identifying initial patterns in the data relating to the research purposes and revising the patterns in light of incoming information.

A major finding in this study was that youths' perceptions of science changed dramatically during grades 1-12 in five major categories. The categories were the nature of science, content of science, methods of learning science, methods of practicing science, and the value of science. Several dimensions of student perceptions were described within each category. The findings also included the examination of the differential influences of the classroom science programs, the schools, the school system, and the community upon students' science perceptions. Although classroom science programs strongly influenced

students' views of science in many categories, students' perceptions of the nature of science and the value of science were sometimes more closely affiliated with parent and community mores.

It was concluded that youths' understandings of what science is are worthy of further investigation because (a) they reflect one aspect of shared local culture and (b) there was evidence in this study that students' science perceptions influenced their classroom performances. Additionally, it was concluded that comparison of students' science perceptions in a given community to science experts' views would provide a basis for improving local science programs.

THE DEVELOPMENT OF PEDAGOGICAL CONTENT KNOWLEDGE OF BEGINNING HIGH SCHOOL CHEMISTRY TEACHERS WITH A STRONG CHEMISTRY BACKGROUND BUT NO FORMAL TRAINING IN EDUCATION

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The purpose of this study was to investigate the development of pedagogical content knowledge of beginning high school chemistry teachers in Spain who had never received any professional training in education but who had excellent chemistry knowledge background.

In most countries prospective high school teachers receive a professional training which lasts between six months and two years. The time devoted to professional training in Spain is considerably less than in other countries. It only represents 1% of the total teacher education time. The other 99% of the training is in specific subject matter, which means that Spanish high school teachers have an unusually strong background in the subject matter they are going to teach.

Since Spanish high school teachers do not receive any formal training in education, we were able to assume that their pedagogical knowledge when they enter into teaching was constituted by personal experiences as learners. It was reasonable to hypothesize that pedagogical knowledge would be gained "on their feet" through an intense interaction with students and peer teachers, and it would have the form of pedagogical content knowledge.

The framework taken in the present study is a combination of a phenomenological approach to knowledge construction and Shulman's approach to teachers' knowledge development.

Two beginning high school chemistry teachers with an excellent chemistry background participated in the study. One of them won the best chemistry student award in 1986 given by the Universitat Autònoma

de Barcelona. The other teacher was formerly conducting organic chemistry research at the Universitat de Barcelona, where he earned his Ph.D. degree.

The present study shows that teacher development is an interplay between knowledge structures and teachers' immediate environment. Although both beginning teachers were extremely well qualified, only one taught in an environment which positively fostered his pedagogical content knowledge development. The shift from a well organized chemistry content knowledge to an emerging pedagogical content knowledge took place through the discovery of students' learning processes and abilities to think. The present study gives support to the effectiveness of providing an environment with an explicit, structured, and student-centered philosophy and curriculum to the beginning high school science teachers who have never received formal training in education but who have an excellent content knowledge background.

#### PERCEPTIONS OF RESEARCH SCIENTISTS AND SCIENCE EDUCATORS REGARDING SCIENCE EDUCATION

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Improvement in science teacher education has been called for by several science and science education organizations. The concept of synergy is suggested as a model for enhanced improvements in the overall preparation of science teachers due to positive interactions between groups responsible for science teacher education: scientists and science educators. To determine if there was a common ground for dialogue between these two groups, a 30-item Likert-type survey was sent to scientists and science educators in Ohio and Georgia. This study determined that areas of strong agreement exist between the two responsible groups regarding some aspects of science education. For example, scientists and science educators both agree that science teaching in high school and college are not the same. Areas of less agreement have been identified which suggest that increased interactions between the responsible groups could produce clarification among issues of importance. For example, scientists and science educators disagree when it comes to offering different science classes for teachers of K-6 and for science majors. Clarification of issues where less agreement occurs is necessary for optimum efficiency of science teacher preparation to result from changing the requirements for teacher education, such as those proposed by the Holmes group. This study suggests specific areas where dialogue has the greatest chance for success.

THE EFFECTS OF MEIOSIS/GENETICS INTEGRATION AND  
INSTRUCTIONAL SEQUENCE ON COLLEGE BIOLOGY  
STUDENT ACHIEVEMENT IN GENETICS

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The purpose of this research was to manipulate two aspects of genetics instruction in order to measure their effects on college, introductory biology students' achievement in genetics.

The study was conducted as a true experiment and utilized a fully randomized 2 X 2 factorial design. One independent variable was the degree to which meiosis was instructionally integrated with genetics. At one level of integration, meiosis was treated separately from genetic inheritance. At the other level, meiosis was used in genetics contexts to explain the results of gametogenesis. The other independent variable was instructional sequence. One sequence, similar to that found in many biology texts, dealt first with monohybrid autosomal inheritance patterns, then with sex-linkage. The alternate sequence, suggested by R. R. Tolman, was the reverse.

Instruction was individually delivered via microcomputer tutorials to 42 engineering and science majors enrolled in a Purdue University introductory biology course. Computer-delivered instruction was chosen to control for teacher effects.

The criterion test was developed by the investigator and measured a subject's ability to define genetics terms, state relationships between terms, and solve various types of familiar and novel genetics problems.

The criterion test scores were analyzed using two-way ANOVA's and revealed the following. In terms of the test overall, the average score of the subjects who received integrated instruction was higher than that of those who received the non-integrated instruction. With respect to the individual test tasks, the Tolman sequence groups scored significantly higher on the definitions task than did the non-Tolman groups. However, the non-Tolman groups scored significantly higher on the monohybrid genetics problem. Finally, the groups which received integrated presentations scored significantly higher on two novel genetics problems that required a meaningful understanding of the role of meiosis in genetic inheritance.

In terms of genetics instruction, these results favor the integrated approach. However, the sequence results are less clear, providing conflicting evidence as to the general efficacy of the alternate approaches.

THE DEVELOPMENT AND EVALUATION OF A CHEMISTRY CURRICULUM  
FOR NURSING SCHOOLS IN ISRAEL

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A very diverse population of students choose nursing as a profession in Israel. Although chemistry is basic for studying nursing, most of these students have not studied chemistry in school for longer than a single year - usually in Grade 10.

We have developed a chemistry curriculum for nursing schools, tried it out, and evaluated it. This curriculum meets our aims, which were identified in a preliminary needs assessment:

- 1) It forms a basis for advanced nursing courses, such as biochemistry and pharmacology.
- 2) It is relevant to the activities of nurses in both hospitals and clinics.
- 3) It can be applied to students with different backgrounds in science.
- 4) It can increase the usual lack of interest of nursing students in studying chemistry.

A chemistry curriculum, "Chemistry for Nursing Schools," was therefore developed in the form of a book containing seven chapters including: why nurses should study chemistry, important molecules and ions in the human body, clinical laboratory tests, acid-base equilibrium in the human kidney, and functional groups in organic chemistry, as well as many case studies.

During the academic year 1985, the "Chemistry for Nursing Schools" course was studied by 400 student nurses, in ten nursing schools. The implementation of this course included discussions with teachers teaching the new curriculum, the development of teaching aids, and an evaluation using pre- and post-achievement and attitude tests.

The curriculum, which takes 25-50 lessons, was used in two types of nursing schools: those that prepare their students for a B.A. degree in nursing (academic schools) and those that prepare their students to be registered nurses.

Half of the schools used the full curriculum, including all the questions and exercises, the teaching aids, and examinations suggested by us. In these schools, the gap which had existed between students

of academic and non-academic schools was closed, or considerably reduced. The gap which had existed between high and low ability students of non-academic schools was also reduced. In schools which used the curriculum as auxiliary learning material, only high ability students gained any measurable benefit.

In the affective domain, students (who read the "Chemistry for Nursing Schools" textbook) reported that the material was clear and helped them to understand the subjects. They also indicated that the case studies and other examples contributed to their understanding of the relationship between nursing and chemistry. In the post-course evaluation, using an open attitude questionnaire, it was found that students are enthusiastic about the new textbook. Both teachers and student nurses indicated that the new curriculum fulfilled a need for a chemistry course for nursing schools, contributed significantly to the improvement of the image of chemistry, and, not least, diminished the anxiety the study of chemistry often caused.

AN ASSESSMENT OF STUDENT KNOWLEDGE IN FOURTH, EIGHTH, AND  
ELEVENTH GRADES OF SCIENCE AND NATURAL RESOURCE  
CONCEPTS RELATED TO ACIDIC DEPOSITION

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This study assessed the knowledge of Maine's 4th, 8th, and 11th grade students' knowledge of acidic deposition. A representative sample of public school students (n=180) was interviewed on twelve (12) concept principles considered critical to a full understanding of acid deposition. These included geological, meteorological, ecological, political, and economic concepts. Student knowledge was rated on each principle on a scale of complete, high partial, low partial, or no understanding. Common misconceptions were also noted. Generalized concept statements were written based upon current student knowledge for each grade level involved and were used to identify similarities and differences between grade levels. Our conclusions have implications for the construction of an acid deposition curriculum based upon student knowledge, which directly addresses common student misconceptions.

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