DOCUMENT RESUME

ED 438 166 SE 063 165

AUTHOR	Costner, Kelly M., Ed.; Reed, Michelle K., Ed.
TITLE	MSaTERs: Mathematics, Science, and Technology Educators & Researchers of The Ohio State University. Proceedings of the Annual Spring Conference (3rd, Columbus, OH, May 15, 1999).
INSTITUTION	Mathematics, Science, and Technology Educators & Researchers of the Ohio State Univ., Columbus.
PUB DATE	1999-12-00
NOTE	119p.
PUB TYPE	Collected Works - Proceedings (021)
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	Educational Change; Elementary Secondary Education; Evaluation; Foreign Countries; Higher Education; *Mathematics Education; *Science Education; *Technology Education
IDENTIFIERS	Representations (Mathematics); South Korea

ABSTRACT

The Mathematics, Science, and Technology Educators and Researchers of The Ohio State University (MSaTERs-OSU) is a student organization that grew out of the former OSU Council of Teachers of Mathematics (OSU-CTM). Papers from the third annual conference include: (1) "Gender, Ethnicity, and Science" (Terry Arambula-Greenfield); (2) "Assessment: The Link between Curriculum and Instruction" (Daniel J. Brahier); (3) "Who's in Charge Here? The Development of Teacher Ownership in an Inter-Disciplinary Environmental Modeling Project" (Andrea K. Balas); (4) "An Overview of Some Characteristics of Today's College Science Students Attending Liberal Arts Colleges" (Andrea K. Balas and John R. Mascazine); (5) "Serving At-Risk Students through Technology Education" (Phillip L. Cardon); (6) "An Exploratory Analysis of Children's Concepts of Rational Numbers: Evidence from Students' Paper Representations" (Matthew D. Conley and Stephen J. Pape); (7) "The Mechanics of School Reform: Case Studies in Mathematics Education" (Kelly M. Costner and Sigrid Wagner); (8) "Bringing Undergraduate Biology to Life with Model Ecosystems and Imaging Technology" (Robert Day); (9) "Serving the Underserved: How to Increase the Participation of Women and Minorities in the Sciences" (Kimberly J. Gibson); (10) "TIMSS: What Can We Learn about Teaching?" (Beth D. Greene and Marlena Herman); (11) "Writing in Mathematics Classes: How Can Students Benefit?" (Kimberle A. Kelly and Beth D. Greene); (12) "MSaT MEd Preservice Teachers' Perceptions of Pedagogical Constructivism" (Youngsun Kwak); (13) "Research Trends in Mathematics Education, 1995-1997" (Hea-Jin Lee, S. Asli Ozgun-Koca, and Teresa H. Rehner); (14) "The Unique Needs and Characteristics of Monozygotic Twins as Learners" (John R. Mascazine); (15) "Science: It's a Family Thing" (Judy Ridgway); (16) "The Y2K Problem in U.S. School Mathematics: A Comparative View" (Mourat Tchoshanov); (17) "Cloning in the News: The Popular Press as a Means for Informal Science Education" (Lynda C. Titterington, Suzanne Shaw Drummer, and Joyce Miller); (18) "Analyzing Student-Generated Representations of Complex Data Sets" (R. Paul Vellom); (19) "Teaching to the Imagination--How to Integrate Science, Mathematics, and Technology within a Humanities Curriculum" (Steve Winters); (20) "MSaT in the Educational System of Korea" (Hea-Jin Lee, Hyonyong Lee, and Kyungsuk Park); (21) "A Comparison of Middle School Technology Education Curriculum between Korea and the United

States" (Kyungsuk Park); and (22) "Feuerstein's Instrumental Enrichment: What Does It Have to Do with Mathematics Education?" (Parisa Vafai). (ASK)

Proceedings of the
Third Annual Spring Conference
of

The Mathematics, Science, and Technology Educators & Researchers of The Ohio State University

MSaTERs

Saturday, May 15, 1999

Arps Hall
College of Education
School of Teaching and Learning
Mathematics, Science, and Technology Education

Editors:
Kelly M. Costner
Michelle K. Reed

MSaTERs Spring Conference Committee 1999

Michelle K. Reed, Co-chair	Proceedings
Marlena Herman, Co-chair	Registration
Kelly M. Costner	Program, Proceedings
Kimberly Gibson	Registration
Beth Greene	Booksale, Program
S. Asli Özgün-Koca	Catering
Chris Merrill	Technical Support
Greta Robertson	Catering
David Westwood	Publicity
Douglas T. Owens	Faculty Advisor

Mission Statement

The ***Mathematics, Science, and Technology Educators & Researchers of The Ohio State University*** (*MSaTERs-OSU*) is dedicated to improving the teaching and learning of mathematics education, science education, and technology education through the following objectives:

- to promote improved teaching practices and research in mathematics education, science education, and technology education;
- to encourage commitment to professional growth and continued professional improvement;
- to promote unity and communication between and among students in mathematics education, science education, and technology education;

Membership is open to all those interested in the advancement of mathematics education, science education, and technology education.

Editors' Preface

The Mathematics, Science, and Technology Educators & Researchers of The Ohio State University (*MSaTERs-OSU*) is a student organization that grew out of the former OSU Council of Teachers of Mathematics (OSU-CTM). Our integrated group consists of those interested in mathematics, science, and technology education, and includes preservice students in our MEd program, practicing teachers in our MA programs, and students in our PhD programs.

In 1997, OSU-CTM held its first annual Spring Conference, a day-long series of presentations on research, teaching, and professional development by and for graduate students in mathematics education. Following this tradition, the *MSaTERs* group sponsored a similar conference in 1998, the Second Annual Spring Conference, for graduate students in mathematics, science, and technology education. The present volume of proceedings contains papers accompanying the sessions in our Third Annual Spring Conference, held in May 1999.

The first two papers in this collection are from invited speakers (faculty members from other institutions) for our plenary sessions, while the remaining papers are from the day's regular sessions. All entries reflect the essence of the authors' presentations, and the proceedings as a whole are intended to serve as a record of the conference events for those who were not able to attend.

Kelly M. Costner

Michelle K. Reed

December 17, 1999

Contents

Poster Presentations

Featured Speaker Sessions

Gender, Ethnicity, and Science

Terry Arámbula-Greenfield
Women's Studies & Science Education
University of Hawai`i
tag@hawaii.edu

This presentation is an overview and summary of a series of interrelated investigations I have conducted in Hawai`i over the past several years. I was interested in Hawai`i because of its nontraditional ethnic context. That is, rather than the usual situation with one dominant ethnic group and one or more minority groups, in this context all groups constitute minorities, with four being particularly numerous: Japanese-Americans, Caucasian-Americans, Hawaiians, and Filipino-Americans. In such a nontraditional context, my questions centered on whether or not traditional gender and ethnic differences in science achievement and attitudes would still be maintained. To explore these questions, I gathered statewide data on science achievement, attitudes and interests, and participation.

These factors were examined in a series of schools across Hawai`i. Data were obtained for students in grades 3-12, representing all four major ethnic groups. Science achievement was assessed using the science portion of the Stanford Achievement Test. Science attitudes and experiences were assessed using a combination of three instruments: the Student Attitude Questionnaire (Simpson & Troost, 1982), the Perceptions of Science and Scientists Survey (Mason & Kahle, 1988), and the Science Experiences Survey (Mason & Kahle, 1988). Participation in science activities was assessed for three dimensions: science classrooms, science fairs, and science museums. Information regarding science classrooms was provided by both state historical records and direct observation, the first to determine enrollments in science courses and the second to determine the level of actual student participation in science classes. Information regarding participation in science fairs was provided by state historical records. Information regarding participation in an interactive science museum was provided by direct observation.

On the whole, it was found that more differences related to science achievement and attitudes were accounted for by ethnicity and even grade level than by gender; in addition, there was little interaction between ethnicity and gender. With respect to science achievement, Caucasian- and Japanese-American students outscored Hawaiians and Filipino-Americans at all grade levels; however, this division probably reflects socioeconomic differences more than ethnic differences. But unlike studies in other areas, there were no consistent or statistically significant science achievement differences between the sexes. With respect to science attitudes, Caucasians expressed the most positive attitudes towards science; they also expressed the most positive perceptions of their own science ability and achievement. Hawaiians generally expressed the least positive attitudes and perceptions. Younger students tended to express more positive attitudes towards science than did older students, and this was especially true for girls, whose science attitudes tended to decline most dramatically over the years. Other than this the major gender differences in science attitudes and perceptions was that males were much more likely than females to consider science a masculine field, and to believe that being a scientist required a very high level of intelligence. This varied somewhat by ethnicity and grade in that, as they got older, Caucasian boys were less likely and Japanese boys were more likely to express this belief. Predictably, males also reported more experiences with physical science activities.

Another finding that also contradicted the situation in other studies was that, in this state girls are as likely or even more likely than boys to enroll in even the highest-level science and mathematics courses. Further, whereas in other studies boys are observed to take over the physical manipulation of laboratory materials and to leave the data recording to the girls, in this state girls frequently are active participants in their science classes, including both discussion and laboratory activities. That is, at every grade level girls were fully as likely as boys to both perform science experiments and to record data; they did not relinquish active laboratory participation to boys at any level. Girls also initiated as many teacher-student interactions as did boys, and this was particularly true for older girls. As in other studies, however, they did not receive as much teacher attention or reinforcement as did boys. Also as in other studies, boys were more likely to be off-task than were girls.

Gender-related similarities and differences can carry over outside the classroom as well. For example, in this state there are gender differences associated with science fair participation but, unlike in other areas, here the differences favor girls. In fact, for the past 20 years of the nearly 40-year history of this state's science fair, girls have participated at a higher rate than have boys. And girls' favored project topics have not differed greatly from those of boys, as both have traditionally favored life science over the years: for girls the top two topics have been botany and medicine, and for boys they were zoology and botany. But boys differed from girls with respect to their third favored topic, which for girls was zoology and for boys was engineering. In fact, overall boys were more likely than girls to prepare physical, earth, and math/computer science projects. More significantly, girls have been generally less likely than boys to prepare projects based on experimental research, frequently choosing to do library-based research projects instead. This means that, although girls are participating as actively in science fairs as boys are, they are still not getting as much experience in scientific inquiry. Further, what experience they do get tends to be oriented towards the life sciences.

Gender differences were observed even in non-academic settings. In particular, interactive museum exhibits hypothetically represent a science experience readily available to both girls and boys, but this does not mean they actually are utilized equally by both sexes. In this study most of the exhibits, whether related to life or physical science, drew both sexes, but the more game-like and exciting activities drew the most children. Still, there were apparent differences in exhibit utilization. For example, throwing balls, rolling marbles, spinning around on a turntable, slapping an air cannon, etc., were consistently popular with both sexes but especially with boys; exhibits involving competitive activities also were particularly popular with boys. On the other hand, exhibits requiring more sustained but less "exciting" activity to produce a result—such as stimulating sequential muscle movement with levers, tracing a figure using its reflection, solving a puzzle, etc.—tended to be utilized more seriously by more girls than boys. But these apparent differences may have been based on accessibility more than on choice. That is, when boys favored a particular activity they tended to monopolize it, precluding girls from using it even when girls were lined up behind them waiting a turn; when girls did finally get a turn boys tended to pressure them to leave. This is in line with the findings of earlier studies, which suggested that girls' lack of physical science experiences does not reflect a lack of interest as much as a lack of opportunity.

Overall, then, the "answer" to the question of whether gender and ethnic differences are maintained in a nontraditional ethnic context is mixed. Ethnic differences in science achievement reflect socioeconomic differences, which would be expected in a more traditional ethnic situation. Gender differences are less overt in that girls' participation and achievement in science generally is greater here, compared to boys, than in the more traditional contexts in which they have been studied. Much of this may be due to parental expectations related to ethnicity and immigration. But there is still much that can be done to narrow gender and ethnic gaps, both with respect to the classroom and to extra-curricular activities, and here schools and teachers can play a major role. For example, they can encourage girls and ethnic minorities to take more science and mathematics courses, and then make the courses more appealing and exciting and ensure that every student participates actively. They can focus more heavily on inquiry-based learning and problem solving in science activities, structured within a group setting to foster critical thinking as well as individual participation. They can provide a diversity of hands-on experiences for all children. They can provide a greater diversity of role models in textbooks and films as well as in person. And at a higher level, universities can ensure that teachers are trained in both effective pedagogy and relevant science content, including scientific inquiry. Because if we do succeed in getting more girls and ethnic minorities into science and mathematics but do not offer them really good classes, ultimately we can more harm than good.

References

Simpson, R. D., & Troost, K. M. (1982). Influences on commitment to and learning of science among adolescent students. *Science Education, 66*, 763-781.

Mason, C. L., & Kahle, J. B. (1988). Student attitudes toward science and science-related careers: A program designed to promote a stimulating gender-free learning environment. *Journal of Research in Science Teaching, 26*, 25-39.

Assessment: The Link Between Curriculum and Instruction

Daniel J. Brahier
Mathematics Education
Bowling Green State University
brahier@bgnet.bgsu.edu

Well good morning everyone. This is probably an appropriate session to begin with and to think about these connections between math, science and technology and framing it around the general topic of assessment. I have spent probably more time working with assessment issues in the last four or five years than anything else at the university. I have been working on four different assessment projects that were funded through Eisenhower grants.

This idea of integrating struck me because we have been doing a lot of things at the university across departments. For example, in the secondary education program when students take methods courses and are out in the field a couple of days a week, they take a block of classes that involves assessment and reading in the content area. The students take a technology in education class and a math or science methods class at the same time. They are in a block so that the assessment person is working with us and making sure that they are hearing the same kind of stories in the assessment class that they are hearing in the methods class. Generally, each semester I team with one of the science instructors and the two of us work together and do a seminar on assessment because so many of the same principles that are true in math education assessment carry over into technology and science. There is not any necessity to repeat our efforts and so we try to work together on some of those topics. What I would like to do is try to give you a little bit of the vision of assessment as a link between curriculum and instruction.

I guess I started out many years ago in my teaching career thinking of assessment as something that you do at the end of the chapter or the end of the unit or when you have taught a lesson to see if the students really got the point. In the end I have decided that assessment is not something necessarily that you do at the end, it is something that you do during, every minute of every lesson that you teach. Every morning and afternoon as we are teaching a class we are constantly assessing what our students are doing. The trick is to take some of that assessment data and use it to try to help us to teach better.

I used to play in a band and then I played by myself for quite a while with an acoustic guitar and a piano and that sort of thing. In the early days of my performing I used to get out on stage with a set list of about fifteen songs I was going to play. I very quickly realized that you could not play set lists. You are playing to an audience and so when you get out on stage and start to look around and see people not paying attention to the song you realize that the next song better be a different kind of song. What I then started to do was roughly write out a few things that I would like to do during the set and then go into it and start to play from there. After I had been doing this for a couple of years I realized that I had a lot of these songs in the back of my head what I needed to do was play to the audience and not to the set list. So when I got out there I would start out with a first song. I would see what kind of reaction I got and then I would take the performance in that direction. What songs I play on any given night is going to depend on what I feel the audience really needs in that particular setting. I think the same thing is true when it comes to teaching. You get in the classroom and you know what the general objective is.

I teach an eighth grade class. I have 21 eighth graders at St. Rose school in Perrysburg and I teach them from 7:15 to 8:15 every morning. I do it to keep myself fresh in the classroom. When I walk into that class every morning I know the major thing I am going to try to get across. I know that we are going to be constructing an irrational number on a number line and that is my major focus for the morning. Now exactly what examples I am going to use to get there I do not know but I have got a few of those sketched out. I do not know what my class is going to need until I get in there. Knowing what my class needs is what assessment is all about. When I give an example of a problem I want see how the students react to it. I give them something to work on in a group and see if it stumps them or if they seem to be able to figure it out. I have to have planned well enough that I can go in different directions as I move along.

I have been doing a lot of assessment lately, of the world in general. I was assessing some of the politicians that are out there and I ran across this one in the Missouri Council of Teachers of Math Journal. What is the difference between Al Gore and an algorithm? The difference is that Al Gore has no rhythm. Which I just thought was sort of interesting. To let you know that I will not only beat up only on Democrats I will play on Republicans a little bit. This was from 1992 when Pat Buchanan was running for president. The headline read "Buchanan speaking to supporters in Plymouth, Michigan. Did not directly acknowledge failure but he did admit to having been bulldozed by Mr. Bush". He said, "Candor does command us to concede that geography and time were not on my side in the last two weeks my friends," he said to the onlookers. "We had a campaign in ten states, that is a third of the nation." I am not sure which nation he lives in. I do know that some of the same types of mistakes he made are common in our world.

I was camping in Colorado Springs last summer and I drove by a sign that said there would be a Sunday evening barbecue from 6:00 to 7:30. The dinners were $6.50 and kids are half price at $3.50. Unfortunately what has happened is that our assessments often times tell us whether or not students can do the skills, but it does not tell us whether they really understand the mathematics. This is where I start to be kind of nervous about some of these things that are out there. I will give you an example. Several years ago I joined one of these CD clubs. The first month I was in it I got a mailing that said they were having a three for one sale. I thought that was a pretty good deal because each one of the CDs costs around $15. If you take three for the price of one that is going to cost me $15 and I am going to get three for that so that is about $5 per CD. The second month I was I got an ad in the mail and I discovered the first CD you buy is around $6 and the second one is around $5 and the third one is around $4. When you add those together and divide by three that is about $5 per CD also. So the price seems to kind of establish itself at $5 per CD. The next month I got an add in the mail that says buy one get two free. Okay I will buy one for $15 and get two more free. But guess what? I still spent $15 for three CDs. That is $5 a piece. The fourth month here comes the ad, selections are 66% off. Well 66% off of $15 is still $5 so the price of a CD is still $5 in the fourth month. The ad comes out in the fifth month and it says all selections are two thirds off. Two thirds off from$15 is still $5. So the price of a CD after six months had very well established itself at $5 a piece. I started to think about how this is an assessment issue. There are a lot of people in this world that can do the mathematics of being able to figure out a percentage or being able to figure out figure out a fraction but they do not really understand what is going on here. The advertisers are smart enough to know that when they put those things out in different ways, buy one get three free, 66% off, etc. that they are going to tap into some kind of mathematics that somebody does not understand. The general public may be able to do the calculation but they do not really understand it and they think they are getting a much better deal than they are.

The issue becomes what is it that we are really focusing in the math classroom. In 1995 the assessment standards the National Council of Teachers of Mathematics said that assessment is an information gathering process. It is interesting that whenever I do any kind of an informal survey and I try to get some definitions for what assessment is, usually people will tie assessment to things like grading, testing, quizzes, and homework. They are things that are very numerical and have some type of a final score or evaluation of a students performance. What I would like us to think about is assessment in a much broader way. It can be as informal as watching. It can be interviewing. It can be discussing. It can be a project or a presentation. It is not so much just a matter of the presentation skill itself but the content that underlies it. In the standards documents, specifically in the assessment standards, it talked about the importance of using assessment for a lot of different purposes. Not only is it important to be able to recognize whether or not students have achieved what was wanted, but also to look at how instructional decisions are made and how we evaluate programs in terms of their effectiveness over the long haul. Making instructional decisions is really critical to me. In fact it is probably something that I emphasize in my methods classes more than anything else. The assessment has to help us to make those instructional decisions. We do not want to wait until the end of the chapter or the end of the unit or the end of the investigation to figure out whether or not the student actually understands what is going on. Once we find out where their knowledge level lies we can start to tweak our lessons to fit the needs of our students if our assessment practices are sharp.

There are six proposed principles of teaching and learning in mathematics and not too surprisingly one of those six principles is assessment. It is something that I do a little bit of everyday to get a sense of whether my students are progressing at the rate that I think they are progressing. What we have to do is take a close look at the data that we collect and ask ourselves how well we really know our students. Are they learning the kind of things that I am hoping and wanting them to learn? I will give you a really simple example of this. There is a child in a kindergarten class that was filling out a sheet. The purpose was to number each row of boxes in order one, two, three. In question number one Mona went to the store, she got fruit, and milk and she took the food home. Number the boxes one, two, and three. Now this same student had question number two marked wrong. The child wrote in the first box that they take a bath. In box number two he wrote that he puts on his clothes. And in box number three he gets out of bed. But what the teacher does not know is when the child takes baths. The teacher's assumption is that he gets out of bed in the morning, takes a bath, puts on his clothes and then goes off to school. The reality is that he could very well be taking a bath at night, he putting on his pajamas, going to bed, and then in the morning he gets out of bed. Which makes perfect sense. It bothered me a little bit that this answer was "marked wrong" because it was not wrong. It was his interpretation of the way that one lives their life, which is to take their bath at night and then get up in the morning. His interpretation of the situation and what the teacher was looking for were two very different things. We start to think about that and we wonder if this is a matter that the student did not understand the mathematics or the sequencing or is it a matter that they just did not have an opportunity to explain themselves.

Sometimes we give kids an opportunity to explain themselves and we get a little bit surprised by it. I had an undergraduate in one of my methods classes that did this assessment project where she had students try to do some rounding and explain how they got their answers. She asked them to round to the nearest one hundred and then explain how they got their answer. So the first student rounds 364 to 400. Here is how he got the answer. Find the place, look next door, five or greater, add one more. 850 rounds to 900, why? Find the place, look next door, five or greater, add one more. On one she told them that rounding 447 to 500 is incorrect and asked them explain why. This is incorrect because I found the place, looked next door, five or greater, add one more. Now the chant is okay to some degree as long as you do not forget any of the words that are in the chant, because if you do then you are in trouble. This goes back to this whole idea of what is it that we are trying to teach in mathematics in the first place. Does this student have any type of a visualization of what it means to round a number to the nearest one hundred? It may not look like too big of a deal but I want to share a true story with you, an assessment that a friend of mine in the Toledo area was doing. She was observing in a fourth grade classroom where students were being asked to round these numbers to nearest ten. In the districts course of study it says that students have to be able to do that with 70% accuracy in order for the teacher to be able to check it off as a mastered objective. There was a little girl in the back of the room that goes along rounding and I will tell you what she did. She did 56 to 60, 39 rounds to 40, 21 stays 21, 50 is 50, 47 goes to 50, 64 stays 64, 18 rounds to 20, 13 rounds to 20, 25 rounds to 30 and 89 rounds to 90. Then she turns her paper in. The teacher picks up a red pen and she says that is wrong and that is wrong and that is wrong. So she got seven out of ten which is 70% so she goes over to her grade book and checks off mastery of that objective. Now here comes the differences between a quantitative measuring of whether the student can do the skill versus a qualitative understanding of does the student really recognize what it means to round a number to the nearest ten. Does this student understand how to round to the nearest ten? Probably not, we would probably have to back and maybe ask the girl some questions and interview her. The teacher did not do that. She handed the papers back. The little girl goes to walk out of the room and my friend Pat walked up behind the girl and asked to see her quiz for a minute. She told the girl that she noticed that she missed some. The girl said she knew she got three of them wrong but that they only had to get seven right. Then Pat asked the girl if she knew why she missed the three that she missed. The little girl said no and in fact she thought she got them right and the teacher made a mistake grading them. Pat asked her to explain how she got those answers. She told her the teacher taught them a rule for rounding. You are supposed to look at the number that is in the ones column and look at the number next to it. If it is bigger round up, if not leave it alone. Six is bigger than five so that rounds up to 60. Nine is bigger than three so that rounds up to 40. But one is not bigger than two so you should just leave that one alone and the same thing for 64 where four is not bigger than the six. Three is bigger than the one so you round that up to 20. The important thing here is that the girl only missed two words of the teacher's algorithm, "than five". If you pull the "than five" out then the rule she has used works perfectly well. The girl did not recognize that we are talking about looking at the number next to it and deciding whether it is bigger than five. Just if it is bigger. So because of that misunderstanding of the algorithm and no understanding of what it means to round numbers, she has no idea what it means to round to the nearest ten. However the ten questions the teacher asked just happened to be designed in such a way that it was possible, and she did, to get seven out of ten correct without understanding the concept at all. Now that is the fear of the child with the last paper that had the chant. Because if that child forgets anything about the chant then all rounding for the rest of her life goes down the drain, because she does not understand what it means to round. What she does have is some kind of a rule and if the rule does not work then it is impossible to go back and reconstruct the crime. Maybe there is a place in the world for inquiry based teaching. If we can construct that understanding of what it means to round ourselves then if we forget the chant then we can always go back and reconstruct the rule.

This becomes a major assessment issue and one of the things that I suggested was to ask more of a two-part question. Giving the students a number and asking them a couple of simple questions with an explanation is going to give us a lot more understanding of what that girl understands than a worksheet with 10 or 20 questions on it. The fact of the matter is that anytime that you ask students to solve a math problem and put the final answer in a line and all you are checking is that final answer you have sent out a very important message to the students that the answer is the only thing you care about. Once they learn that that is what you value in the classroom, they begin to think of mathematics as being a process of getting an answer and putting it on a blank. The same thing is true with memorization in science and with completing some kind of a basic skill on a computer screen. The students learn that that particular skill and getting answer is exactly what you are looking for. I think that is a problem. That prompted one student to say to his teacher, "I think you will find my test results are a pretty good indication of your abilities as a teacher." The fact of the matter is that whether we like to acknowledge it or not, when our students do not do well on a particular assessment, or conversing when they do do well on an assessment, that does have some kind of a reflection on how we taught that particular topic. Grant Wiggins said, "Reform begins by recognizing that the test is central to instruction and any test or exams inevitably cast shadows on all prior work. So they do not only monitor standards but also set them. Students acknowledge this truth with their plaintive query, 'is this going to be on the test?'" If I say to you that something is going to be on the test they immediately know that they better know it. We do send messages to our students on a regular basis, based on the way that we are choosing to assess their progress. If we think that something is really important we have to come up with some way of assessing it.

A test could be a written test. It could also be some other type of an assessment that our students might do. I will give you an example. A few years back I was doing some consulting for a local school district that had a competency test that they were trying to refine. They had an objective in their course of study that said that the student would understand what it means to take a square root and be able to calculate square roots. They showed me their competency test and here is how they were measuring that. Question number 25 on the test had them find the square root of 64. Question number 26 had them find the square root of 49 then the square root of 81 and then the square root of 36 and they were allowed to use calculators. If a student got three out of four of those right then the computer automatically checks off that they have mastered that objective. I asked how the eighth graders were doing on that part of the test. They said that, ironically, over the last five years, they have had a 100% passing rate. I asked what they meant by ironically. The students do not really have to know anything about square roots to be able to answer those questions. We turned the tables around a little bit and I suggested some things like what number has a square root approximately equal to 17.32. Let them use a calculator. Have then draw a picture or a diagram that shows why the square root of 25 is equal to five. Can we score these two papers on a rubric and decide whether or not they really understand square roots. They have done this for three years and the passing rate now is at 17%. What we have learned is that they really do not have a deep understanding of square roots. They can calculate a square root with a calculator, but so what? The issue here is do they really understand what it means to take square roots and can they go both ways with them. It is the difference between the students mastering the mechanical skills versus really understanding what is going on. We will not know whether they have actually mastered the concept unless we have asked the question in sort of nontraditional ways. An example of that might be if you have an open-ended question that you ask the students. Suppose that you wanted to use your calculator to find the square root of twenty to the nearest thousandth. But unfortunately the square root button on your calculator is broken. How would you do that? One eighth grader wrote if he had no square root button there was still a way to figure it out. First he would think of it this way, what two numbers multiplied together equal twenty. Well fives time five is too high and four times four is 16 so obviously the answer has to be a decimal. Now we need to start punching in numbers like 4.5 or 4.4 but they do not work so we need something between 4.4 and 4.5. Let's try 4.46 and he goes on and eventually figures it out to a few decimal places. This is teaching me whether or not the student really understands how to go backwards and square these numbers to figure out what the original number was. It is a much deeper way of being able to assess their understanding of square roots.

As I have worked with this for the last few years I have come up with a graph of what assessment can do. I labeled the x-axis as the student's ability to demonstrate their understanding of a concept. The y-axis represents their actual understanding of the concept. The ideal line of inference, which is the line y equals x, is the ideal situation where if the student does not understand a concept very well then they also should not be able to do it very well on assessments. That is a tricky thing to achieve because we all know we often times go in to take some kind of a written test and we really know our stuff but we blow it anyway. Or we go in on the written test day and we feel kind of shaky but we made a few good guesses and we got a high grade and we cannot believe we scored that high. Those things happen because the assessment is not perfect and so we are trying as an instructor to get our students on the ideal line, but the fact of the matter is that our assessments do not always get us there. We end up with students that have a higher level of understanding than we actually measure, or the students that have a lower level of understanding than the data will indicate. I think our job as teachers is to try to get our students as close as possible to that line. What NCTM has said in the standards documents is that to get students on that line we need more than what the traditional paper and pencil will tell us about student's performance. So we start looking for other ways of being able to measure what they know. I thought it was interesting that the 1989 MSEB publication said, "We must ensure the test measure what is of value not just what is easy to test. If we want students to investigate, explore and discover assessment must not measure just mimicry mathematics." Which I think is a critical thing here.

What are different ways that we can test our students' understanding? We have a lot of data on this. One of my favorite places to draw from is the National Assessment of Educational Progress, the Nations Report Card, or the NAEP test. On the test a few years ago they asked a question that is still one of my favorites, called Trina's budget problem. This question was asked of eighth graders around the country and the purpose was to imbed some relatively simple computation within a problem where there were a variety of different ways that the student can go with it. It was scored with a rubric on a scale of zero to five. The key issue here was that it was more problem solving based than computation based. Here is what the question said, "Trina wins a seven day scholarship worth $1000 to a basketball camp. Her round trip travel expenses to the camp are $335 by air or $125 by train. She can choose between individual instruction at $60 a day or group instruction at $40 a day. Her other expenses are fixed at $45 a day. She does not plan on spending any money other than the scholarship. What are all of the choices of travel and instructional plans that she could afford to make?" They scored these on a rubric from zero to five. A zero was a no response. If the student writes nothing on the paper and they just leave it blank and hand it in they get a zero. 22% of the eighth graders in the country did this back in 1992. More than one out of five students had no idea how to even start that problem. They gave them a gift of a one on the rubric if the student wrote that they did not know or wrote something down on the paper that had absolutely no meaning at all. Here is an example, "Add everything other than the scholarship and you get 230." So the student writes something on the paper but it is meaningless and this was 37%. This means that 59% of the students either left it blank or wrote something meaningless on the paper.

In order to score a two on the paper you have to have said something like, she could take the train to camp and individual instruction and eat everything and not run out of money. There are no calculations shown but they have at least explained something and realized that there was a possible way that this girl could pull it off within the scholarship. In that case they get a two on the rubric. That was 22% of the eighth graders. To get a "partial" score of three you had to actually go through and show your work and go through one of the choices and 15% of the students fell into that category. To get a "satisfactory" score of four you had to have at least two of the approaches or all three of them with a miscalculation somewhere along the line and that was only 2% of the eighth graders. To get the highest score on this paper, which was a five, you had to have shown all of the different options of what actually works and that was 2% of the population. Now the way that the NAEP people score the test is that a four or a five is a passing score. Anything from a zero to a three is less than we would expect for an eighth grader. On this question 96% of the eighth graders fell into the zero to three range. Only 4% of them acceptably answered the question. One of the things that the documents mentioned about this problem is that it was a little bit surprising because the entire problem relies on very basic simple computation. There was nothing more than a little bit of multiplication and adding two numbers together. So it is not the computation and the arithmetic that is the problem here. It is the problem solving that is the problem. Think back to what traditional assessment has done for these kids across the years. Typically what we have done is said add these two numbers and write the answer on the blank. Multiply these numbers and write the answer on the blank. Divide these two numbers and write the answer on the blank. They can do that. The problem is that if you put that into a couple of sentences and they have to think a little bit and problem solve they cannot do that. So what they have learned is that the traditional assessments have painted a picture that mathematics is all about memorizing some skills and demonstrating those in such a way that you get answers that you put on blanks. As soon as we open the question up and ask the students to explain their thinking, to show what different possibilities are, and to really solve a problem, suddenly we get a different picture of what students can do. In a journal not too long ago it said, "The issue here is not whether or not you can add the numbers, it is whether it is appropriate to add the numbers."

The professional teaching standards it give us an interesting challenge. Back in 1991 NCTM released the professional teaching standards, which painted this picture of classrooms as math communities, as using logical and mathematical evidence as verification rather than just relying on the teacher to give you the answers and this whole idea of connecting math, conjecturing, and problem solving. One of the things it makes me think about is that if we believe that this document is a good idea then we should be doing this in the classroom. We also have to think about what type of assessments we are doing in the classroom to promote these. If we tell our students that problem solving is important but then on the tests everything is computation with answer blanks they quickly realize that what we are saying and what we are doing are two very different things. As soon as we decide that these things are critical we have got to think about how our tests and our various assessments are going to look different from how they used to. A lot of people will argue that the old way of doing tests is still an efficient way and if we just had it the way that we had it in the olden days life would be good. I wrote an article about that for the Ohio Journal because I feel pretty strongly about it and I quoted Will Rogers who said, "Schools aren't as good as they used to be, but then they never were."

As we start looking at things to assess our students progress we look at things that go beyond the paper and pencil assessments. One of the things is observation. Looking at your audience, looking at your students, talking to them, and finding out what they are actually thinking as you are moving along. One of the things that I thought was interesting was that the first written school exams were not instituted until 1845 by Horace Mann. Prior to 1845 all assessment was done by the teacher looking at the class and asking some questions. Observe what you do on a day to day basis. I do not have to have a written test. One thing that Horace Mann said really bothered me. He says that a written exam is "impartial, removes all possibility of favoritism and prevents the officious interference of the teacher." That is pretty strong language. I started thinking about that and I thought how objective a test really is. Often times you see folks that are giving multiple choice tests and calling them objective tests. Could I make that test so difficult that nobody would pass it? I probably could. Could I make it so easy that everybody would get them all right? Of course I could. How subjective is this? Completely, because I am the one who is making up the test.

What I have to think about as I am looking around in the classroom is that I need to adequately assess whether or not my students are progressing. I do kind of a weird thing with my eighth graders. With my eighth graders from time to time I do give written tests. I would never advocate completely getting rid of written tests. The issue for me is putting them in context. When I give a written test I have historically enjoyed grading the best tests at the end. So normally what I do is I get my 21 tests in and I put them in order from the tests that I think the students will struggle the most on to the students in my class who I am almost certain got scores in the high 90's. Then I grade them in that order. That way I spend most of my time and energy scoring the papers where students did not do as well first and I leave the easy ones until later. Now I learned a lesson from that. The lesson is, if I can sit there and order those papers from the students who are most likely to do the worst to those who are going to do the best, and if I already know that before I give the test then why am I even giving the test. Well I know why, because I want evidence to support my gut feeling. So what the written test is going to do is to verify something that I really already know. What that teaches me is that the observation that we do on a day to day basis tells us a lot about what our students know and do not know before you ever get to a point of giving a written test. That data is already there in front of you.

I tell my eighth graders at the beginning of the year that there are four things that I am focusing on in my classroom and they are problem solving, communication, reasoning, and connections. Those are the four process standards in the NCTM standards document from 1989. We have added a fifth one, which is representation in the new standards. I told my students that these are the things that I am looking for in the class. I make notes about how well they are doing each of these four things. Not a note for every student every day just what I happen to observe on a given day. I am very careful at the beginning of the year to explain to them that this is what I am looking for when I look for problem solving skills. I want to see your ability to deal with a unique situation or problem that you have never encountered before. I want to see your ability to try and use different problem solving strategies. When I am looking for communication I want to see how well you work with your teammates. I want to see if you share your answers, if you help other people, if you can communicate in writing, and if you can communicate verbally. My students need to know that up front because one of the things the assessment standards are very clear about is that assessment has to be an open process. So I will take some notes about that and include that as part of an assessment of a project or a team assignment that my students are doing. I was doing that a couple of years ago with a group of classroom teachers in a workshop setting and somebody mentioned that it is really hard to take too many notes during class time because we are so busy in the classroom moving from table to table and they suggested that maybe what we needed was some kind of a checklist. I asked my participants in this workshop to get their heads together and list for me some examples of behaviors that students might exhibit in a classroom if they were good problem solvers or good reasoners. They came up with: if I was seeing reasoning going on in the classroom I would see students who could justify their thinking, recognize a reasonable answer, students that are asking questions like why, what if, what would happen, couldn't we just, and knowing when to stop or when it is that they are finished and the problem has been solved. It is important to know when you go into the classroom what behaviors you are expecting to see in your students. You should establish those ahead of time and tell your students ahead of time. Your purpose is to try to get to know your students better and you can do better things with instruction and curriculum if you are doing better things with assessment.

What we assess and how we assess it will communicate to our students what it is that we value. When we were kids we used to say if you ask a stupid question you get a stupid answer. I think the same thing is true in education. You ask good questions you get good answers. If the open-ended questions that you ask are rich enough you will learn a lot more about students than a simple question is going to teach you. So we keep looking at those things and asking what kind of information we can get from our students. I ran across a good example of this in a Peanuts cartoon recently. Marcy answers the teacher, "yes ma'am 16" and Peppermint Patty tells her to, "just stay subdued that's the secret." "The North Sea ma'am" Marcy answers another question. Peppermint Patty tells her again, "don't be a loud mouth. Subdued is the word, subdued." And Marcy says, "subdued?" "Yea subdued is the word Marcy. It is my new theory Franklin, I have been too loud in class, and from now on I am subdued. Go ahead Franklin you will learn". Then Franklin answers a question, "the sable antelope". He answers another one, "Yes ma'am the Selkirk Mountains." Peppermint Patty remains, "totally subdued." She gets her paper back and it says D- and comments that she seems hesitant to speak up in class. I think there is an interesting message in this cartoon. Peppermint Patty did not realize that the teacher wanted her to speak up in class. In her mind the ideal model student was the subdued student that did not say anything. In the teachers mind the ideal student was somebody that speaks up and puts their piece forward. That is a problem because when she is in the classroom she does not realize what the teacher values. Once she gets this assessment back you can guess that the next day in class she is going to speak up and stop being so subdued because now she knows that it is affecting her grade, that it is valued and that this is something that the teacher is looking for on a day to day basis. Do we want our students to learn this, this and this? If so how are we going to assess it, because however we assess it is going to communicate to our students what it is that we value in the classroom.

Our students value a lot of different things in the classroom. I was working with a school district scoring a set of competency tests a few years back and they had this question on here about your church is having a festival. It costs fifty cents to play the game. You roll one die and it has got one through six on it and the other one is 0,0,2,2,4,4. You win the game if the sum of the cubes is 1,2,3,8,9 or 10 and you lose if it is 4,5,6 or 7. Is the game fair? Explain your answer in sentences, with a chart or through a diagram. We wanted students to be able to go through and think about what the different possibilities are when you toss those two die and put it in a matrix form or something like that. One student wrote this on his paper, "why is it that we spend more time trying to figure out what happens when you roll a die twenty times than we do with things that actually affect us? Why is everyone so naive thinking we will actually use this stuff when the truth is that all most of us need to know is, 'would you like fries with that?'" I remember when I first read that I was scared by it and then I laughed at it and then I went back to being scared. This is a student who clearly does not see the relevance of mathematics, has not to this point, and probably is trying to cover up for the fact that he does not know how to solve the problem. The standards talk about connecting math to the real world and the National Research Council and the National Science Standards talk about the same thing. This whole idea is the application of science in the real world to make decisions and so forth. Those are critical pieces and so on a day to day basis we have to ask if our students are being engaged in activities and assessments that show them these links. Which is an interesting question. It is not all too different from this one that was in Hi and Lois where she comes in and says, "I will never understand the male mind. Bluto is in there sorting his baseball cards for the umpteenth time. He has got them sorted by player, number, and team statistics. But he still keeps putting his socks in the shirt drawer." Our students react relative to what is important to them. It is important to make real life connections to class. If we believe that this is important then lets assess their ability to make real life connections because if the test boils down to a basic skills thing again the students will quickly learn that those real life connections were phony.

The Ohio Proficiency Test gives us a prime example of how curriculum, teaching and assessment are almost inseparably linked. The proficiency test has a given set of outcomes on it that every student in the state is supposed to have mastered by fourth or sixth grade and soon to be tenth or twelfth. As soon as that assessment comes forward and you know what the outcomes are that your students are supposed to have mastered you have no choice but to take another look at your curriculum and ask if you are teaching the right kinds of things. If this assessment is going to have open ended questions, short answer questions, use of calculators, and maybe even graphing calculators in the new tenth grade test, then we have to ask if the teaching we are doing on a day to day basis is promoting the kind of things that are going to be on that assessment. In that sense the assessment is driving the curriculum and the teaching. When the Ohio Math Model came out and we saw that the curriculum was supposed to be problem solving and reasoning based, there was no choice but to make teaching more problem solving and reasoning based because that is what the curriculum calls for. If that is happening then assessment probably has to change also. When any one of those three components is changed there is no choice but to change the other two in some kind of a profound way. If you do not change them then you will be measuring your students on something very different than what you are trying to promote in the classroom.

I believe it is important in the classroom that students learn to do things like ask some of their own questions and pose some of their own problems. I give a project in the eighth grade class every year where I ask my students to pose their own good problem and to come up with possible solutions to it. One of the first things that I do is I ask them to tell me what a good problem is. Last year they said that a good problem is one that makes you think, is realistic, requires some algebra thinking skills, is interesting, evokes curiosity, is one that we can relate to, does not necessarily have just one or any solutions at all, lends itself to having different ways to solve it, has enough data presented, and is worded well enough to be able to solve it. I believe that the more our students are involved in being able to come up with some of their own rubrics, problems, and assignments, the more they will take ownership for what is going on in the class—and that also helps them to be able to understand what the critical pieces are. Once again there is a link between the curriculum and the assessment that we do on a day to day basis. It prompted this student to say, "How do you expect me to learn anything when you are the one who keeps asking all of the questions?" Or put another way this student says, "Should we put down what we think is right or what we think you think is right?" That is a big part of it because our students are looking for those kinds of answers in the classroom.

Over the last four years this Eisenhower project I have been working with has followed a model where we introduce our participants to the NCTM curriculum and teaching standards to motivate this idea of change. One of the things that we do early on in the project is we have the teachers go out and try various assessments with their classes and they realize where the gaps are in learning. When they come back and they have realized that their students really did not understand everything they thought they did. Once we know that, it sort of pushes us to teach in a different way. It links the assessment with the teaching again. What they have devised on the web sites are a number of different ideas of these strategies for assessment. They have written assessment plans and so any one of those web sites has got upward of about 80 or 90 to about 150 different assessment ideas that teachers have come up with of things that they are doing in their classes that were tried and true and seemed to work for them. When you see results that your students have on alternative assessments that is when you start to realize that maybe they cannot do what you thought that they could do so well. It pushes us to make some changes in our day to day teaching. Steve Meiring, who is now retired from our state department, I once quoted as saying , " Instead of saying I cannot do this because.... . Say I can do this until..... ." We are always in the process of pushing teachers to think about a different way that they can assess their students progress and to think about what kind of messages are our students getting about the nature of mathematics by the assessments that we are doing. I will close with this question, suppose that a heart surgeon was assessed in their ability to save patients lives solely through the use of true-false tests through medical school. The question is would you trust that surgeon to operate on you child. The fact of the matter is if on a day to day basis in our classes we believe that problem solving and reasoning are important things in the curriculum and that we are promoting that with our teaching then our assessment must match that so that the whole cycle fits together well. Thank you for coming this morning.

References

Dossey, J.A., Mullis, I.V., & Jones, C.O. (1993). *Can students do mathematical problem solving?* Washington, DC: U.S. Department of Education.

National Council of Teachers of Mathematics. (1998). *Principles and standards for school mathematics (discussion draft).* Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1995). *Assessment standards for school mathematics.* Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics.* Reston, VA: National Council of Teachers of Mathematics.

National Research Council. (1989). *Everybody counts: A Report to the Nation on the Future of Mathematics Education.* Washington, DC: Mathematical Sciences Education Board.

Ohio Department of Education. (1990). *Model competency-based mathematics program.* Columbus, OH: Ohio Department of Education.

Wiggins, G. (1992). Creating tests worth taking. *Educational Leadership, 49* (8), pp. 26-33.

Regular Sessions

Who's in Charge Here?
The Development of Teacher Ownership in an Interdisciplinary Environmental Modeling Project

Andrea K. Balas
Science Education
The Ohio State University
balas.6@osu.edu

This is an era of national reform in science education. The *National Science Education Standards* (NRC, 1996) urge the development of "curriculum patterns that are developmentally appropriate, interesting and relevant to students lives (p. 212)." *Science for all Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics and Technology* (AAAS, 1989) states that "It is the union of science, mathematics, and technology that forms the scientific endeavor and that makes it so successful (p. 25)."

In this atmosphere of change, four schools in the Columbus area are participating in a nationally funded Environmental Protection Agency grant project focused on enriching school science curricula. This project is essentially a collaborative classroom teacher and student effort resulting in model building on a water-related topic that incorporates variable manipulation and outcome prediction. Project activities include accessing available data, selecting subsets, and creating visual models using computers and software to illustrate the important role models play in understanding complex natural systems. The project is infused into the existing science curriculum but incorporates the disciplines of science, mathematics, and computer technology. In addition to the model building, the project also develops strategies for building local capacity in three regions of the country for the purpose of broadening the experiential base for developing curricular modules, instructional practices, and student research methodologies that will work in typical classrooms having diverse student audiences and socioeconomic conditions.

The focus of this study is the motivation of the teachers to participate in this innovative project and the development of their ownership of the project. Data collection occurred during four teacher planning sessions over a three-week period as the teachers, project director, and technical expert prepared for the project's two-week summer institute. Data in the form of videotapes and material artifacts were collected. The videotapes were viewed and catalogued, and promising interactions were coded for further analysis. The complete set of records permitted reexamination of developing trends, patterns, and styles of behavior. In addition, the teachers responded to interview questions as a data source. Study questions included:

1. What factors motivated the teachers' participation in a new project?
2. Did the teachers develop project ownership?
3. How do the teachers' actions reflect ownership of the project?

Initially, the teachers were extrinsically motivated to participate in the project. In the project planning sessions, they were generally interested but passive participants. The project director and technology expert governed the planning meetings. The teachers often asked questions about themselves, their classrooms, and/or their students in regard to the project. The teachers were learners, specifically learning the computer program that would be the tool used in the mathematical modeling of an environmental question. They were concerned about the project goals, their role in the project, materials, supplies, and support for themselves and their student interns. As the teachers grew and embraced the project, they began to identify ways they could be involved personally in the project. In this phase, they became more active participants, but the sessions were still led by the director or technology expert. Examples of such events included bringing supplemental materials from the newspaper, sharing a flyer for a local workshop that would provide background information for the project, and sharing ideas and strategies for using existing classroom computers efficiently and effectively. At the end of the fourth planning session, the teachers had developed a sense of ownership in the project. The leadership of the session was assumed by the teachers. They tabled the discussion planned by the director and technology expert and pressed for a discussion of the two-week summer workshop. They actively voiced their needs, ideas, and the methods of instruction and material presentation they felt would be optimal for their students. The director and technical expert became the listeners as the teachers began to organize and schedule the daily events. As the teacher became familiar with the project, they developed an understanding of their role, a comfort level with the technology, and a focus for their classroom. As their ownership in the project developed they became more vocal and active participants in the collaboration with the director and technology expert. As the school year progressed, each of the teachers developed their ideas about project implementation in autonomous and varied ways to meet the needs of their students, curriculum, and school environment.

This study illustrates, via videotapes, artifacts, and interviews, the processes teachers employ to develop ownership for an innovative funded project. The study illustrates how the teachers who were extrinsically motivated to participate in a project worked to explore, understand, and develop a personal classroom implementation strategy. The variety of extrinsic motivators provided an impetus to move thoughts into actions. Extrinsic motivation can internally progress from behaviors that were extrinsically motivated but become internalized and then self-determined (Rigby, Deci, Patrick, & Ryan, 1992). From this study, a portrait of the successes and difficulties teachers encounter in this progression while planning an innovative, interdisciplinary program for "all" students emerges. The understanding of teachers' initial motivation and reaction to externally funded and directed projects can provide policymakers important perspectives on implementation of these programs or projects to facilitate project goals and objectives.

References

American Association for the Advancement of Science. (1989). *Science for all Americans: A project 2061 report on literacy goals in science, mathematics and technology.* Washington, DC: Author.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

Rigby, C. S., Deci, E. L., Patrick, B. C., & Ryan, R. M. (1992). Beyond the intrinsic and extrinsic dichotomy: Self-determination in motivation and learning. *Motivation and Emotion, 16*, 165-185.

An Overview of Some Characteristics of Today's College Science Students Attending Liberal Arts Colleges

Andrea K. Balas
Science Education
The Ohio State University
balas.6@osu.edu

John R. Mascazine
Science Education
The Ohio State University
mascazine.1@osu.edu

The students enrolling in college science courses at small liberal arts colleges today represent more diversity than the students of the 1970s and 1980s. The recent decade has seen an increase in nontraditional students. In some college courses, nontraditional students actually outnumber students who have recently graduated from high school. However, many of the science courses being taught today have not been revised to address the needs and demands of nontraditional students. The purpose of this study was to consider some of the characteristics of college students who are attending liberal arts institutions in the central Ohio area.

Data was collected from three different classes of students studying undergraduate science as nonscience majors. Quantitative and qualitative methods were used to survey and follow-up student responses. Information was collected dealing with each student's previous formal and informal science education, their knowledge about how they learn, and what experiences they considered to be most beneficial to their understanding of science concepts. Students also completed the Dunn, Dunn, and Price Learning Style Inventory (PEPS version), and the Cutter Hemispheric Preference Indicator.

The results of work with over one hundred students from the three classes revealed the following themes and patterns.

1. Nontraditional college students did acknowledge and use their learning style strengths and preferences when given opportunities and choices to do so.
2. Many nontraditional college students who took the Cutter Hemispheric Preference Indicator expressed strong preferences for right- or left-hemispheric processes.
3. Nontraditional college students achieved higher grades on assignments that were in accordance with their learning style strengths and their hemispheric preferences.

Feedback from students and colleagues indicated that attention to individual learning preferences and hemispheric processing differences does influence one's attitude and achievement in college science classes. While some college instructors have begun to attend to these differences, others remain reluctant to change from traditional teaching methods. Data from this study can be useful in advocating and providing a diverse array of methods and assessment tools appropriate to the needs of diverse nontraditional college students.

Serving At-Risk Students Through Technology Education

Phillip L. Cardon
Technology Education
The Ohio State University
cardon.1@osu.edu

The enrollment of at-risk students in technology education classes is pervasive throughout the country. However, little is known about why at-risk students would want to take technology education classes, how they value these classes, and whether desiring such courses and valuing technology education actually help them to remain in school.

A review of literature revealed a lack of research regarding at-risk students in technology education. Additional literature was reviewed to determine characteristics of at-risk students (Batsche, 1985), learning styles (Brandt, 1990) and theories regarding at-risk students (Bosworth III & Savage, 1994; Dewey, 1900, 1916, 1938; Korwin & Jones, 1990; Pinar, Reynolds, Slattery, & Taubman, 1995; Nuthall, 1997), and why alternative learning methods are important to at-risk students (Bowen, 1992; Dunn & Dunn, 1979; Midkiff, 1991; Wheeler, 1988).

Qualitative research methods were used to study how at-risk students view a technology education program. Participant-observation techniques were utilized in observing, interviewing, and documenting the various evidence regarding eight at-risk students in two technology education courses at the same school.

The philosophy of the school was determined to be focused on helping students to gain lifelong skills for employment in the community. The philosophies of the students and the technology education program reflected the philosophy of the school.

In learning what the students considered to be important to them, the researcher determined that the students viewed social life and mathematics as important. As for the industrial technology program, the students viewed hands-on learning, life skills, and problem-solving skills as important to them. Additionally, five of the eight students in the study remained in school because of their enrollment and continued opportunity to enroll in technology education courses.

Implications from the study include the following ideas. First, at-risk students have been determined to learn best in hands-on learning environments (Jackson-Allen & Christenberry, 1994). This finding could help support the use of hands-on instruction in other school subjects. Second, at-risk students viewed technology education as a subject that would give them technical skills that they could use to obtain work after high school.

Many times during the interviews and observations, the students mentioned their employment desires following school, and indicated that the technology education program could assist them in obtaining employment. A possible follow-up could be to study at-risk students in other subjects to determine if they feel the same way toward those subjects.

Third, of the eight at-risk students involved in the study, five of them indicated on several occasions that they would not be in school if it were not for their enrollment in the technology education program. The students viewed this program very favorably, and showed enthusiasm whenever they were engaged in the curriculum. This may imply that technology education programs could be used to help keep at-risk students in school. In addition, studies could be undertaken to determine if these hands-on methods of teaching could be incorporated into other school subjects to help the students want to learn and have more reasons to remain in school.

References

Batsche, C. (1985). *The high school drop out: Vocational education can help.* Normal, IL: Illinois State University. [ERIC Document Reproduction Service No. ED 262 213]

Brandt, R. (1990). If only we knew enough. *Educational Leadership, 48*(3), 3.

Bosworth III, F. M., & Savage, E. N. (1994). A concept for an environment for teaching and learning problem solving. *Journal of Technology Studies, 20*(1), 10-14.

Bowen, R. C. (1992). Infusing technology into education. Paper presented at the New Horizons Conference for the Virginia Community College System. [ERIC Document Reproduction Service No. ED 345 759]

Dewey, J. (1900). *The school and society.* Chicago: The University of Chicago Press.

Dewey, J. (1916). *Democracy and education.* New York: Macmillan.

Dewey, J. (1938). *Experience and education.* New York: Collier.

Dunn, R. S., & Dunn, K. J. (1979). Learning styles/teaching styles: Should they . . . can they . . . be matched? *Educational Leadership, 36*(8), 238-244.

Jackson-Allen, J. & Christenberry, N. J. (1994). *Learning style preferences of low- and high-achieving young African-American males.* Nashville, TN: Paper presented at the Annual Meeting of the Mid-South Educational Research Association. [ERIC Document Reproduction Service No. ED 387 758]

Korwin, A. R., & Jones, R. E. (1990). Do hands-on, technology-based activities enhance learning by reinforcing cognitive knowledge and retention? *Journal of Technology Education, 1*(2), 39-50.

Midkiff, R. B. (1991). *Learning style needs of at-risk students: Teaching math and social studies the way they learn.* [ERIC Document Reproduction Service No. ED 331 632]

Nuthall, G. (1997). *Learning how to learn: The social construction of knowledge acquisition in the classroom.* Paper presented at the Biennial Conference of the European Association for Research in Learning and Instruction. [ERIC Document Reproduction Service No. ED 414 043]

Pinar, W. F., Reynolds, W. M., Slattery, P., & Taubman, P. M. (1995). *Understanding curriculum.* New York: Peter Lang.

Wheeler, C. (1988). *Correlation between remedial students and learning styles: Implications for computer assisted instruction.* Eastern Washington University, Master's Thesis. [ERIC Document Reproduction Service No. ED 297 294]

An Exploratory Analysis of Children's Conceptions of Rational Numbers: Evidence from Students' Paper Representations

Matthew D. Conley
Integrated Teaching and Learning
The Ohio State University
conley.27@osu.edu

Stephen J. Pape
Mathematics Education
Integrated Teaching and Learning
The Ohio State University
pape.12@osu.edu

Even students who can "do the math" often have little or no understanding of the "why's" associated with rational numbers. That is, children's conceptions of fractions are often superficial or incomplete at best. Without question, fractions are complex, and to understand fractions is to understand a rich mathematical tapestry. For example, 3/4 can simultaneously be thought of in terms of three parts of a four-part whole as well as thought of and represented in the form .75. Additionally, 3/4 can be viewed as a comparison of three objects to four objects (as in a ratio) or as the arithmetic operation of three divided by four. Kieren (1976, as cited in Behr, Harel, Post, & Lesh, 1992; Behr, Lesh, Post, & Silver, 1983) has delineated the above conceptions of fractions into what he calls subconstructs. His subconstructs of rational numbers are: part-whole comparisons, decimals, ratios, quotients, operators, measures, and ordered pairs.

Through exposure to these multiple representations, children come to form deep structural knowledge about rational numbers and are able to define them in their broadest sense. A fraction is an element of an infinite quotient field consisting of infinite equivalence classes (Behr, Harel, Post, & Lesh, 1992). Children are able to make this generalization only when they can conceive of each of the subconstructs and how they are interrelated.

Van de Walle (1994) concurs that children should see multiple representations of rational numbers; however, he suggests that understanding the part-whole construct is perhaps most important. When children have a clear understanding of this construct, they recognize that a whole unit is separated into matching parts with some number of matching parts identified (Langford & Sarullo, 1993). This subconstruct seems to form a base upon which the other subconstructs can be built.

The subconstruct that we examine in our research is that of fraction as an operator. Behr, Harel, Post, and Lesh (1992) state that the operator concept of fractions suggests that the rational number 3/4 can be thought of as a function applied to some number or set. The numerator stretches the quantity while the denominator shrinks it. For example, when 3/4 is applied to a quantity such as the expression "3/4 of 12," the numerator (3) causes an extension of the quantity while the denominator (4) causes a contraction.

To facilitate children's understanding of multiplication and division with fractions, they must first alter their traditional understanding of multiplication and division with whole numbers. Whereas multiplication of whole numbers increases a quantity and division of whole numbers decreases a quantity, children need to understand that rational numbers do not follow this same pattern. Children should be encouraged to use models and draw representations of problems such as [3/4 of 8] and [3 x 5/6]. Our research examines how children depict such problems.

Methods

Participants

The participants in this study were volunteers from a pool of sixth- (N = 288) and seventh-grade (N = 335) students who attended a public intermediate school in New York City and who provided consent to participate in a larger study. The school's population is predominantly white (73%) with 20% Hispanic, 5% Asian, and 3% African American students. The sample included 42 sixth-grade (47.6% male, n = 20; 52.4% female, n = 22) and 53 seventh-grade (30.2% male, n = 16; 69.8% female, n = 37) students who volunteered to participate.

Procedures

The instruments for the larger study included a Student Background Survey, a Student Agreement Form, two forms of the Verbal Protocol Stimulus, and a Computation Test. The Student Background Survey was used to record the students' date of birth, gender, grade and class in school, most recent report card grades in mathematics and language arts, and the most recent CTB Reading and CAT5 Mathematics standardized achievement test scores from their school files. Although two measures served as the main instruments in the larger study—namely, (1) Verbal Protocol Stimuli, and (2) Computation Test—our focus in this paper is on children's depictions of fractions from the latter measure. The computation test consisted of 12 items and was developed to assess the participants' computational skills and knowledge related to the mathematical concepts and operations necessary to solve the word problems on the Verbal Protocol Stimulus. The problems of greatest interest to this report are those that required the participants to visually depict the multiplication of a fraction by a whole number and a fractional part of a set of objects.

The participants completed all measures on two separate days in an office within the library of the students' school. On the first day the researcher met with each student individually to complete the videotaped Verbal Protocol session. During the second session, the students completed the Computation Test in groups of approximately five.

Children's visual depictions of multiplication by a fraction were recorded and categorized by the researchers. Solutions were categorized into correct and incorrect responses. Beyond these divisions, error patterns were sought, and various representations of correct answers were examined.

Results: Fraction Representations

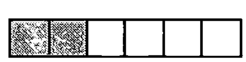
Students were asked to depict through illustration the following examples:

(a) 3 x 2/5 (three times two-fifths)

(b) 1/4 x 16 (one-fourth of sixteen)

To be successful with these two problems, participants needed working knowledge of the concept of a fraction as well as an understanding of what it means to multiply. Of the 95 participants, nine (9.5%) failed to produce any representation. That is, they either did not attend to the problems or were unable to approach the problems with any level of competence.

A second group of solutions fell into the category including basic fraction misrepresentations. These students were unable to depict the numbers in terms of their fractional parts. An example of this representation would be:

2/5 = 

In this case the student actually depicted 2/6, not 2/5 as was required by the problem. Additionally, these participants were unable to depict a whole number in relation to the fraction. That is, they were unable to illustrate the whole number 3 in terms of fifths, or failed to demonstrate how 3 acts upon 2/5 in this problem. In all, 23 (24.2%) participants fell into this category.

The third category that emerged included representations that resulted from a simple, straightforward translation approach. Participants in this category simply restated the problem in terms of the numbers. Students depicted the numbers correctly, yet failed to understand how to apply multiplication to the problems. An example of the simple translation approach to the problem 3 x 2/5 is:

Students accurately depicted the whole number three and were able to depict the fraction 2/5; however, they failed to demonstrate any understanding of the multiplicative relationship between the two. Thirty participants (31.6%) approached the problem in this manner.

Three (3.2%) participants first solved the problems through computation and then attempted to depict their solution through illustration. Interestingly, two of the three were able to solve the problem correctly through computation. However, only one of these two was able to represent his/her work correctly through illustration.

Finally, 29 (30.5%) of the 95 participants successfully completed at least one of the two problems. As was the case with the unsuccessful participants, the vast majority of the 29 successful participants used region area models to depict the problems. Since the questions did not ask for a solution to the problems, the following example was scored as a correct response to the question 3 x 2/5.

 = 6/5

It should be noted that four of the participants carried the above example to completion and represented their solution as a mixed number. For example:

 = 1 1/5

Participants were slightly more likely to depict 1/4 x 16 using a set model representation. Additionally, depictions of one-fourth of sixteen objects and sixteen one-fourths were accepted as correct responses.

Conclusion

With only 29 (30.1%) of the 95 participants able to correctly represent one of the two problems, our exploratory research suggests that students need to spend more time developing conceptual knowledge of rational numbers. Children can become quite proficient at applying rules and operations to fractions without understanding the meaning behind the procedure. Because 32 (33.7%) of our participants were unable to represent or misrepresented the problems and 29 (30.1%) made simple translations of the problem with no regard to the operation, it seems clear that students would benefit from additional exposure to problems like the two examples presented here.

References

Behr, M. J., Harel, G., Post, T., & Lesh, R. (1992). Rational number, ratio, and proportion. In D. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 296-333). New York: Macmillan.

Behr, M. J., Lesh, R., Post, T., & Silver, E. A. (1983). Rational-number concepts. In R. Lesh & M. Landau (Eds.), *Acquisition of mathematics concepts and processes* (pp. 91-126). New York: Academic Press.

Langford, K. & Sarullo, A. (1993). Introductory common and decimal fraction concepts. In R. J. Jensen (Ed.), *Research ideas for the classroom* (pp. 223-247). New York: Simon & Schuster.

Van de Walle, J. A. (1994). *Elementary and middle school mathematics.* New York: Addison Wesley Longman.

The Mechanics of School Reform: Case Studies in Mathematics Education*

Kelly M. Costner
Mathematics Education
The Ohio State University
costner.1@osu.edu

Sigrid Wagner
Mathematics Education
The Ohio State University
wagner.112@osu.edu

Reform efforts in mathematics and science education are hot topics both within the education community and in the public forum. Many strategies have been employed to facilitate reform, ranging from the formulation of standards and policy statements to training sessions for both pre- and inservice teachers. This project sought to identify school-level characteristics and processes that either facilitate or inhibit reform efforts. The specific focus was on the aftereffects in mathematics in two Central Ohio middle schools of *Project Discovery,* a summer institute for inservice mathematics and science teachers.

Context

Lantern Hill Middle School (LHMS, a pseudonym) has approximately 650 students in grades 6, 7, and 8, 95% of whom are African American. The school is located in a lower-middle class neighborhood in a large urban school district. The principal at LHMS is an African American female who has earned a PhD in education. The school follows a true middle school philosophy, with teams of teachers organized by grade level.

Macon Middle School (MMS, a pseudonym), on the other hand, has only 350 students in grades 7 and 8. The school is 70% white, with mainly working- to lower-middle-class families. The district is considered urban, but the area and the school have a small town atmosphere. The principal at MMS is a white male who has implemented a more traditional junior high philosophy, with teachers organized into subject-area departments across grade levels.

Impressions

LHMS has been designated a "School of Excellence" by its district, and one certainly feels that aura upon entering the building. In the main office is a prominent display of proficiency test scores and media clips. The school involves parents in many

*Funding for this project was provided by the National Science Foundation, Grant #REC-9602137 (J. B. Kahle, Principal Investigator). The opinions expressed herein are those of the authors and do not necessarily reflect the position of NSF.

activities, including an occasional parent exchange program, which one year pulled nearly 200 parents into the building during one school day. The principal and teachers call upon culturally relevant heroes, such as Harriet Tubman, when addressing students and encouraging or admonishing them to do their work. The principal and teachers make use of cordless telephones throughout the building to contact parents directly from the classroom—with the student and in front of his/her classmates. Intense and caring are definitely words to describe the general atmosphere of the school.

MMS is itself a study in contrasts. Although the school building (circa 1920) is unimposing and modest in style and facilities, it almost secretly houses cutting edge technology in a computer lab and television production studio. The school has some unique responsibilities in its district—not only is it the designated Title I school, it is also home to students with special needs due in part to the fact that the building is equipped with an elevator. One gets the distinct impression from the outset that the teachers have a great deal of autonomy—our first contact was through a teacher rather than the principal. In contrast to LHMS, this school is considerably more unassuming and "laid back."

In short, LHMS demonstrates large urban leadership, while MMS demonstrates small urban leadership. Both schools have effective administrations in place, and reform efforts, according to the schools' respective (collective) definitions of reform, have been successful.

Contrasts

Our data, which consists primarily of classroom observations and interviews with students, teachers, and the principal at each, school reveal contrasts in three areas: (a) administrative style, (b) relative influence of teachers on their peers, and implications of (a) and (b) for student equity. Each of these three contrasts will be explained.

Administrative Style

The principal at Lantern Hill is omnipresent and very "hands on" in her approach to her role. She has decidedly high expectations, and is always pressuring her teachers and students to do more and better. There is a clear mutual respect between her and her faculty and students.

While this same mutual respect exists at Macon, the principal's style is quite different. He seems to practice somewhat of a "clockmaker" philosophy—that is, he has set an example and set things in motion for the teachers to follow and pursue to the end.

Indeed, he set an example upon his arrival at the school by applying for a major grant that funded the television production studio. With that precedent, a number of teachers have followed suit with grants that have funded a number of other projects, such as major events and activities for a Women in Science and Engineering (WISE) program. The school has something of an entrepreneurial atmosphere—once can sense that the teachers are actively seeking ways to put their ideas into action, and they are doing so through grantsmanship.

Teacher Influence on Peers

Although each school had only one of its teachers participating in *Project Discovery*, the effects of that one participant have been distinctly different. At Lantern Hill, the teacher was elementary certified. Although the faculty at LHMS has monthly subject area meetings and weekly team meetings by grade level, the one *Discovery* participant has not had much of an effect on her peers. Practices and approaches encouraged by *Discovery* are the consequence of other teachers' personal philosophies and not the result of the *Discovery* teacher's influence.

At Macon, on the other hand, the one *Discovery* participant was certified in secondary mathematics. It is clear that the two other full-time mathematics teachers in the school turn to the *Discovery* teacher for assistance and teaching ideas, both through departmental meetings and on a one-on-one, spur-of-the-moment basis. Further, all three math teachers seek professional development opportunities on their own.

Implications for Equity

At LHMS, the principal chose during the year of our research to focus on improving scores on standardized writing tests. She implemented a school-wide program in writing practice that improved writing scores, but which meant that improvements in mathematics instruction and learning were somewhat neglected. Despite her efforts to improve test scores and general achievement for all students, it is still the case that white students, the minority in this school, tend to outperform the African American students.

At MMS, mathematics receives at least as much attention as other subject areas, in part because of the designation of the school as Title I for all areas, which allows a full-time teacher to oversee the computer lab. Inequalities remain, however: Due to the extensive programming offered by the WISE organization, female students get much more attention than male students in terms of science-related activities.

Influences on Reform Efforts

These case studies revealed two important factors that influence reform efforts: principal support and teacher leadership. At Lantern Hill, reform was defined as improvement of standardized test scores, and through principal support—indeed, pressure—for higher scores, as well as teacher leadership, success was achieved. Specifically, writing scores improved by 12 points in one year—a dramatic leap. At Macon, reform was defined as innovation on the cutting edge, in terms of technology, reform-oriented texts and approaches, and programs such as WISE. Through the principal's support for efforts to obtain funding for such ventures, and through the leadership of the *Discovery* participant, reform by the Macon definition is continually being implemented, as is the propagation of *Discovery* ideas.

Bringing Undergraduate Biology to Life with Model Ecosystems and Imaging Technology

Robert Day
Department of Evolution, Ecology and Organismal Biology
Science Education
The Ohio State University
day.3@osu.edu

As part of a recent review of the undergraduate curriculum, faculty and staff of The Ohio State University Department of Evolution, Ecology and Organismal Biology began exploring new ways to teach their introductory animal diversity class. Traditionally, instructors in this field relied on descriptions of preserved specimens, charts, and models. Live animals appeared rarely, usually only as a curiosity. Students were not engaged in any form of active investigation and showed little interest in the material. When these undergraduates accompanied graduate students as field assistants, they were enthusiastic but disorientated, uncomfortable around live animals, and unable to translate their classroom experience into real world expertise. In order to prepare students more realistically for careers in zoology, we adopted a more constructivist approach emphasizing direct observations of anatomy, behavior, and the ecology of live animals. We accomplished this using a set of carefully managed natural aquaria and a versatile video imaging system (Day, 1996a, 1996b). We believe that the ability to demonstrate the biology of small specimens to a large audience may also prove useful in public schools, national aquaria, and zoos.

Objectives

Over the last two decades, many universities have consolidated or down-sized traditional biological science departments to make way for the applied research and material rewards of new molecular labs. Ironically, this trend has led to a shortage of classically trained taxonomists at the very time they are most needed to catalogue and protect what remains of earth's living diversity. In view of this, what new tools can science educators use to inspire the next generation of biologists and prepare them for their role as stewards of the natural world? At OSU's Department of Evolution, Ecology and Organismal Biology, we considered this question carefully during the construction of our new animal diversity class. From the outset, we wanted to adopt a hands-on approach, in tune with contemporary educational theories that stress the importance of active learning and student participation (Bonwell, 1991). After studying instructor and student evaluations of existing classes, and comparing them with the needs of employers and graduate schools, we came up with the following list of objectives for our new class:

- Encourage student's natural enthusiasm and make learning about animal diversity a more positive experience, especially for non-majors.
- Include as many live animals as possible. Students invariably respond best to visual aids that slither, wiggle, or bite.
- Reduce the use of black and white line charts and text diagrams. Wherever possible replace these with images of real organisms.
- Reduce wear and tear on our preserved specimen collection. Preserved specimens do not inspire students much and often bare little resemblance to their formerly- animated selves. They are also becoming increasingly expensive to replace.
- Incorporate modern technology to help prepare students for the job market of the twenty-first century.
- Encourage students to search for and observe live animals in their natural environment. Teaching students basic observational skills has become especially important, given their typically urban upbringing and consequent lack of exposure to the natural world.
- We felt that contemporary biological education has a responsibility to promote respect for living things and help students appreciate the value of biological diversity in a dynamic ecosystem.
- Our solution must not exceed the limits of available space or funds, and must be permanently sustainable, enabling us to teach multiple classes throughout the year.

The Solution: Model Ecosystems and Video Imaging

After exploring several approaches, we found that our needs could best be met using a set of small aquaria and terraria. Our collection includes displays that mimic tropical marine, temperate marine, freshwater, bog, leaf litter, and savanna habitats. Although the displays are not large or particularly technically complex, they collectively hold many hundreds of animal and protist species including representatives from about fifteen of the major phyla we cover in our animal diversity class. The displays are able to sustain a high level of diversity with less expense and supervision than traditional aquaria, despite the year-round onslaught of sampling and examination by multiple classes of up to forty students.

To ensure that the displays are used as a fully integrated part of our classes, we assembled a video imaging system that has proven invaluable to the "hands-on" approach. The basic components are listed below. Note that although, the total system boasts a wide range of capabilities, most of the components, considered individually, are not particularly "cutting edge." Many pieces were "handed down" as semi-obsolete research equipment we then modified for use in teaching. The remainder was purchased using a $9000 grant from Ohio State's Board of Regents. This grant allowed us to complete two independent, cart-mounted systems that can be used anywhere in the department in a variety of configurations. The system's capabilities can be further extended using the facilities available at OSU's multimedia lab, located in Lord Hall.

Figure 1. Basic components of video imaging system

System 1	System 2
Sony CCD camera , (VHS/SVHS/RGB)	Hitachi CCD camera (VHS/SVHS)
Panasonic VHS / SVHS time lapse VCR	RCA VHS VCR
JVC VHS / SVHS VCR with editing features	Laser 486sx, 8MB ram, 100MB HD
Mac ii ci, 8MB ram, 70MB HD, Mac monitor	SVGA monitor
Mitsubishi multi-scan monitor	Video Blaster video card
Truevision Nuvista-plus video card	Iomega Zip drive, 100MB discs
Iomega Zip drive, 100MB discs	Proscan TV monitor
Proscan TV monitor	Epson Stylus color printer
Epson Stylus color printer	Compound or dissecting scope
Compound or dissecting scope	Cart
Cart	**Total cost* $7000**
12.5mm 6x Zoom lens	
Close focus adapters	
Tripod	
Copy stand	
Total cost* $18000	

* Approximate total cost of listed components or equivalents if purchased new, excluding microscopes.

Special Features of Our Aquarium Displays

To maintain our displays as practical model ecosystems, we adopted an approach influenced by the work of Walter Adey at the Smithsonian Institution (Adey, 1991), and by aspects of the fledgling disciplines known as complexity (Waldrop, 1992), and chaos

(Gleick, 1987). Complexity predicts that complex systems tend towards stability and show emergent properties such as self-sufficiency. Chaos stresses the role of "sensitivity to starting conditions." Our displays are set up to be as ecologically complex and self-sufficient as possible. They rely heavily on their own inhabitants for biological filtration and efficient energy distribution. Some use no electric pumps or filters at all and are almost completely maintenance-free. To increase the diversity of represented taxa, we often use multiple replicates of displays. We have found that small differences between the starting conditions of these replicates tend to eventually produce significant variation of the animal and protist diversity in each. We have also found that long-term sustainability and maintenance of diversity depend on strict adherence to ecological principles in all aspects of the design and management. Theories of island biogeography, ecological succession, and the factors affecting diversity have proven particularly relevant. For a general discussion of these ecological concepts see Colinvaux (1986). For technical details of our microcosms contact the author for a copy of the most recent version of the maintenance manual (Day, in prep.). For details of how we use the microcosms in our animal diversity class, see Day (1994).

The type of aquaria we maintain at OSU is certainly not for everyone. The dense plant growth, swarms of small invertebrates, and absence of rare fish may even lead some aquarium hobbyists to consider them ugly. Beauty, however, is in the eye of the beholder. Natural aquaria are easy to maintain, relatively cheap to run, and spectacularly diverse. They make an ideal tool for biological education at the undergraduate level because of their ability to hold students' interest and develop observational skills. We believe that because of increasing emphasis on conservation and education in public aquaria, small, resilient, natural systems, coupled with the ability to display images to a large audience, could be an educationally fruitful, cost-effective, and environmentally friendly addition to more traditional displays.

References

Adey, W. H., & Loveland, K. (1991). *Dynamic aquaria: Building living ecosystems.* San Diego, CA: Academic Press.

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom.* ASHE-ERIC Higher Education Report. Number 1. Washington, DC: George Washington University.

Colinvaux, P. (1986). *Ecology*. New York: Wiley & Sons.

Day, R. (1996a). The Aquarium as an educational tool. *Freshwater and Marine Aquarium Magazine, 19*(2). Sierra Madre, CA: R/C Modeler magazines.

Day, R. (1996b). *Bringing undergraduate biology to life with model ecosystems and imaging technology*. Proceedings of the Annual Conference of The American Zoo and Aquarium Association. Feb. 28 - March 2, 1996. New Orleans, LA

Day, R. (1994). *Introduction to animal diversity lab manual (GTA version) 1st edition.* Columbus, OH: OSU Dept. of Evolution Ecology and Organismal Biology. Text version available on disk from author.

Day, R. (in preparation). *Maintenance Manual for the Department of Ecology Evolution and Organismal Biology Microcosms, 2nd edition.* Columbus, OH: OSU Dept. of Evolution Ecology and Organismal Biology. Text version available on disk from author.

Gleick, J. (1987). *Chaos: Making a new science*. London: Penguin books.

Waldrop, M. M. (1993). *Complexity: The emerging science at the edge of order and chaos.*. New York: Simon and Schuster.

Serving the Underserved: How to Increase the Participation of Women and Minorities in the Sciences

Kimberly J. Gibson
Science Education
The Ohio State University
gibson.275@osu.edu

This conference presentation will deal with the ongoing problem of the underrepresentation of women and minorities in the field of science. In this presentation I will outline ways these biases can be overcome to make science education that will be equal and accessible to all. I will discuss the problems facing women and minorities and offer some practical recommendations on how to make the science classroom more friendly to underserved groups. I will also discuss some of my own personal struggles of being both a woman and a minority in science. Finally I will discuss how science education reform programs such as Project 2061 and the *National Science Education Standards* address the issue of underrepresentation of women and minorities in science.

The demographics of our schools are rapidly changing. An influx of immigrants from Asia, Africa, the Middle East, Latin America, and the Caribbean has offered a new challenge to teachers. How do we teach students who may not speak English as their first language, come from single parent families, or live in poverty? How do we encourage these diverse populations of students to develop an interest in science? Will the new inquiry learning methods increase the participation of female and minority students?

First we have to understand that students bring their own culture into the classroom. Student knowledge is a result of one interacting and making sense of the culture he/she lives in. As science teachers we need to understand and find ways that students may use their knowledge or views of the world to draw on their prior cultural experiences. When working with minority students, teachers should be aware that these students need to work in a classroom environment that enables and encourages them to use their cultural tools. These tools include language, references to myths, personal beliefs, metaphors, images, preferred learning styles, and the time and space to apply their existing knowledge to problem-solving situations. In many science classrooms and textbooks, the Eurocentric worldview is the one that predominates.

The majority of science teachers are white and male (Carey, 1993). The contributions of women and minorities are often overlooked. We need to facilitate the examination of science knowledge in historical, social, and cultural contexts. We need activities that integrate a science curriculum associated with scientific advances identified with non-Western cultures, or that compares science in different cultures.

Females are another underrepresented group in the sciences. There are complex sociocultural, personal, and educational interactions that must be addressed to increase the numbers and achievement levels of girls in school science. Gender stereotyping is a major factor in the differences in science achievement in boys and girls (Kahle & Damnjanovic, 1997). Young students asked to draw a scientist often draw a white male with bushy hair and glasses working in a laboratory (Barman, 1997). The media often portrays scientists as "geeks" and "nerds." Young girls feel science is not for them and often take less science courses than males (Kahle & Damnjanovic, 1997). Girls often have less experience working with electricity and machines than boys. Boys are more interested in the physical sciences and girls are more interested in the biological sciences (Kahle & Damnjanovic, 1997). Boys participate in more extra-curricular science activities than girls. The media and textbooks often present a gender-stereotyped view of science and scientists. Counselors do not encourage girls to take advanced science courses nor to pursue careers in science. Teachers, both male and female, who were successful in motivating girls to continue to study science practiced directed intervention. That is, girls were asked to assist with demonstrations; were required to perform, not merely record, in the laboratory; and were encouraged to participate in science-related fieldtrips (Kahle & Damnjanovic, 1997). In addition, these teachers stressed the utility of math and science for future careers. The research suggests that teaching styles and other school-related factors are important in encouraging boys and girls to continue in science courses and careers (Baker, 1996). Other things that teachers can do is maintain well-equipped, organized, and stimulating classrooms, encourage parental support, respect students, use non-sexist language in the classroom, and include women scientists in the curriculum (Kahle, 1985). Research has also shown that the use of cooperative learning groups in which roles are well-defined and rotated so that everyone has an opportunity to exhibit competence in a variety of ways increases equity in the science classroom (Baker, 1996). Finally, science courses that stress the value of cooperation and helping can put a female-friendly face on science. Many girls want to become scientists to help people, animals, and the world, but the traditional school curriculum in which science is taught without any context makes expressing these values very difficult. Science should be taught in the context of real world problems.

Science education reform efforts are beginning to address the underrepresentation of women and minorities. For example, one of the goals is to introduce the philosophy of caring into the science standards. In *Science for All Americans* (AAAS) (American Association for the Advancement of Science, 1989), the standard states that students should respect nature and foster a concern for progress toward a safe world. Another goal is to include all students in the learning of science. The *Science Education Standards* (National Research Council, 1995) state that all students regardless of background can learn and do science. These efforts are trying to address the hierarchical, masculine, and Eurocentric biases present in traditional science education.

References

American Association for the Advancement of Science. (1989). *Science for all Americans*. Washington, DC: Author.

Baker, D. (1996). A female friendly science classroom. *Research Matters to the Science Teacher, 9062*.

Barman, C. (1997). Students' views of scientists and science. *Science and Children, 35*, 18-23.

Carey, S. (Ed.) (1993). *Science for all cultures*. Arlington, VA: National Science Teachers Association.

Kahle, J. (1985). Encouraging girls in science courses and careers. *Research Matters to the Science Teacher*.

Kahle, J., & Damnjanovic, A. (1997). How research helps address gender equity. *Research Matters to the Science Teacher, 9703*.

National Research Council. (1995). *National science education standards*. Washington, DC: Author.

TIMSS:

What Can We Learn About Teaching?

Beth D. Greene
Mathematics Education
The Ohio State University
greene.181@osu.edu

Marlena Herman
Mathematics Education
The Ohio State University
herman.91@osu.edu

Policy makers have recognized that literacy in mathematics and science affects economic productivity, and competence in these areas is essential for success in the global marketplace. The Third International Mathematics and Science Study (TIMSS) was conducted during the 1994-95 school year and has been used extensively to compare the mathematics and science achievement of students and the instructional practices of schools worldwide. TIMSS came in the wake of other reports and documents, including *A Nation at Risk* (1983), *National Goals for Education* (1989), *Curriculum and Evaluation Standards* (1989), *Professional Standards for Teaching Mathematics* (1991), and *Benchmarks for Science Literacy* (1993). TIMSS has not only provided data to evaluate progress of U. S. students towards our national goals, but has also acted as a diagnostic tool to examine our educational practices compared to those of countries around the world.

The International Association for the Evaluation of Educational Achievement (IEA), based in the Netherlands, coordinated teams of researchers in each of the 41 participating countries in order to standardize the procedures used. However, each participating country was responsible for funding the collection of data in accordance with the established guidelines. The test was designed to reflect mathematics and science curricular goals from a variety of TIMSS countries, and students were chosen at random to represent the population of their respective countries. Students were selected at three levels: nine years of age, 13 years of age, and students in their final year of secondary school. Participants came from both public and private schools, and tests were given in the primary languages of the respective countries.

Critical Questions

TIMSS sought to study many aspects of schooling in the countries participating. In the U. S., this data has been used to address five main questions:

> (1) Do U. S. students know as much mathematics and science as students in other countries? (2) Are U. S. curricula and expectations for student learning as demanding as those of other nations? (3) How does classroom instruction in the U. S. compare with that of other countries? (4) Do U. S. teachers receive as much

support in their efforts to teach students as do their colleagues in other nations? (5) Are U. S. students as focused on their studies as their international counterparts? (USDOE, 1997, pg. 4).

Data Collection Methods

In order to gain a broad picture of the educational system, several different types of data were collected. (1) Assessments lasting one and one-half hours were given. All students completed evaluations including both multiple choice and free-response portions, while a small number of participants also completed hands-on assessments. (2) Questionnaires were given to students, teachers, and school administrators. Questions addressed beliefs about mathematics and science, teaching practices, and school polices. (3) Curriculum guides and textbooks from participating countries were examined to determine subject-matter content, sequencing, and expected outcomes. (4) In the U. S., Germany, and Japan selected classrooms of thirteen-year-olds in participating schools were videotaped so that instructional practices could be studied and compared. (5) Researchers spent three months in the U. S., Germany, and Japan observing and interviewing educators, students, and parents in order to collect ethnographic case studies. These studies were then used to evaluate the educational and social environments surrounding schooling in these three countries.

Key Results

Achievement

U. S. fourth graders scored above the international average in both mathematics and science, while eighth grade students were below in mathematics. The mathematics achievement seemed to be lagging behind the most in the areas of geometry, measurement, and proportionality.

Curriculum

The majority of participating countries had a national curriculum, with only nine, including the U. S., leaving curriculum decisions for educators at the local level. In addition the mathematics curriculum in the U. S. seemed to compare to the average seventh-grade curriculum for other participating countries, putting our students a full year behind their global counterparts at age thirteen. Even though they are falling behind in mathematics, it is interesting to note that, on average, students in the U. S. spend more hours in mathematics and science classes than students in Germany and Japan.

Many of the reforms headed by professional groups in mathematics and science were still in their infancy in 1995; therefore, their benefit could not be measured with this report. However curriculum comparisons with Germany and Japan show that less high-level mathematical thought is required of U. S. students.

Teaching

Through talking with teachers it was discovered that the U. S. mathematics teacher's goal was to teach students how to obtain answers, while teachers in other countries were more concerned with helping their students understand mathematical concepts. In addition, the majority of Japanese teachers were observed practicing elements of the reform movement, while U. S. teachers reported familiarity with the reform without necessarily implementing it (USDOE, 1997).

Teachers' Lives

U. S. teachers seem to have more college education than colleagues from other countries. German and Japanese teachers undergo long-term structured apprenticeship programs. Further, teachers in Japan reported more opportunities to discuss teaching-related issues than did U. S. teachers.

Students' Lives

Tracking was handled differently in the U. S., Germany, and Japan. Typically students of differing abilities were divided into separate classrooms in the U. S. and Germany. In Japan, however, there was no ability grouping until students gained entrance into high schools, the result of high stakes testing at grade ten. Differences in the content addressed in mathematics courses was seen among ability groups in the U. S., while in Germany and Japan the same concepts were addressed in all groups, and any differences lie in the depth or rigor of approach.

More homework is given and more class time is spent discussing it the U. S., but time spent out of school was about the same for all three countries. However, many of the same distractions are seen in all countries: Heavy television viewing was noted for both U. S. and Japanese students.

Conclusions and Further Plans

There is no easy answer to the question of how to help U. S. students move to the top of these international comparisons, but the results from TIMSS have important implications. Some suggestions made by the TIMSS National Research Center include: (1) Provide better preservice and inservice opportunities to enhance teachers' mathematics and science knowledge; (2) Improve the curriculum's consistency and focus; (3) Increase opportunities for teachers to dialogue within and across subject areas; (4) Align standards, frameworks, instruction, and assessment; (5) Eliminate tracking; and (6) Encourage policy change that will support improved curriculum and instruction.

In order to continue to gain insight and provide countries with information to help with educational reform, the IEA will conduct TIMSS-R, a follow-up examination. Thirteen-year-olds from 40 countries will once again be tested. Not all of the original countries will participate in the follow-up study, while others have joined, but it will be interesting to compare this new data with the baseline information collected in 1994-95, when many of these students would have been in grades that participated in the nine-year-old study. Results planned from this battery of tests are expected in the year 2001.

Resources

Three major publications on TIMSS are available to the public:

I. *IEA's Third International Mathematics and Science Study*

TIMSS International Study Center
CSTEEP, Campion Hall 323, Boston College
Chestnut Hill, MA 02467
phone: (617) 552-4521, fax: (617) 552-8419
email: timss@bc.edu

II. *A Splintered Vision*

TIMSS National Research Center
Michigan State University, College of Education, 455 Erickson Hall
East Lansing, MI 48824-1034
phone: (517) 353-7755, fax: (517) 432-1727
email: request@ustimss.msu.edu

III. *Pursuing Excellence: A Study of U. S. Twelfth-Grade Mathematics and Science Achievement in International Context*

National Center for Education Statistics
New Jersey Ave., NW
Washington, DC 20208-5574
phone: (202) 219-1333, fax: (202) 219-1736
email: timss@ed.gov

Web Sites

- www.nctm.org
- nces.ed.gov/timss
- wwwcsteep.bc.edu/timss
- wwwcsteep.bc.edu/TIMSS1/AboutTIMSS.html
- uttou2.to.utwente.nl
- ustimss.msu.edu
- www.rbs.org/eisenhower/resources/timss.html
- www.enc.org
- www.ncrel.org

References

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford.

Executive Office of the President. (1990). *National goals for education*. Washington, DC: Author. [ERIC Document Reproduction Service No. ED 319 143]

National Commission on Excellence in Education. (1983). *A nation at risk*. Washington, DC: Author.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (1995). *Professional standards for teaching mathematics*. Reston, VA: Author.

U. S. Department of Education, Office of Educational Research and Improvement. (1997). *Attaining Excellence: A TIMSS Resource Kit*. Washington, DC: Author.

U. S. TIMSS National Research Center. *A Splintered Vision*. East Lansing, MI: Michigan State University, College of Education.

Writing in Mathematics Classes: How Can Students Benefit?

Kimberle A. Kelly
Mathematics Education
The Ohio State University
Hilliard Davidson High School
kkelly1964@aol.com

Beth D. Greene
Mathematics Education
The Ohio State University
greene.181@osu.edu

Since the publication of the NCTM *Curriculum and Evaluation Standards for School Mathematics* in 1989, more and more teachers across the United States have tried to incorporate writing into their curriculum to meet the needs of their students. Research has shown that writing in the mathematics classroom has four main benefits for students: (1) therapeutic value, (2) increased learning of content, (3) improvements of learning and problem-solving skills, and (4) alternative mode of assessment (Masingila & Prus-Wisniowiowska, 1996; Mayer & Hillman, 1996; Miller, 1991; NCTM, 1989, 1995).

Many authors discuss the use of reflective journals as a way to help foster students' ability to communicate their feelings and questions (Bagley & Gallenberger, 1992; Davidson & Pearce, 1988; McIntosh, 1991; Mayer & Hillman, 1996; Miller, 1991). Writing improves learning in ways such as requiring the use of mathematical language and identification of problem areas in student thinking (Bagley & Gallenberger, 1992; Davidson & Pearce, 1998). In the area of problem solving, writing is particularly applicable (Davidson & Pearce, 1988). Reflective thinking and writing are processes that involve learners in actively building connections between what they are learning and what is already known, an essential element in the problem solving process. Finally, writing can be used as an alternative mode of assessment. Writing can elicit better communication between teacher and student, give information about the student's misconceptions and beliefs, and give genuine evidence of the student's achievement.

Instructional Implications

Teachers must decide whether or not to include writing in their mathematics curriculum. Consider the words of McIntosh (1991):

> When teachers read students' definitions, misconceptions that may otherwise go unnoticed become apparent, thereby helping teachers identify areas that need reteaching. By reading and responding to the student's writing, the teacher can get a better feel of where the students are confused and what needs to be reviewed or taught in a different way. (p. 242)

It is evident that writing can add to the teacher's knowledge of the students and to the mathematical knowledge of the student.

The addition of writing to the curriculum does change the role of the teacher and the composition of the class. Teachers must develop management skills in order to gain the most from the student's writing. They must be able to distinguish times when writing is appropriate and when other forms of communication or assessment would be just as viable. Students will need time and support to develop their communication skills and mathematical terminology.

Implementation

The purpose of this presentation is to move from the research and assist teachers in the quest of integrating writing into the mathematics classroom. From the perspective of two classroom teachers, we will lead a discussion of ideas that have facilitated our use of writing to assist students in their mathematical growth and provide a forum for sharing other successful examples of integration. We will address four main questions:

How can writing improve learning in mathematics classes?

We will discuss how writing can improve understanding by improving the mastery of concepts and skills, improving communication skills, helping to organize and crystallize thought processes, fostering the development of a more positive attitude toward mathematics, and building confidence. Writing in math classes can also improve teaching because it aids in monitoring student progress, improves the communication between teacher and student, and acts as an effective alternate form of assessment of understanding.

How can the classroom teacher integrate writing into mathematics classes?

We will address both informal and formal methods of integrating writing activities into daily lessons, as well as more time-consuming projects and activities. Some of these forms will be journals or logs, letters to other students, portfolios, examples of creative writing activities, and many more. This area is the focus of the presentation. Many examples and ideas will be shared with audience members and they will be encouraged to share ideas that have worked for them as well.

When does the classroom teacher implement writing into the curriculum?

We will discuss different ways to integrate a writing activity into a lesson or a unit, how much time to spend on it, how the teacher can also participate in the activity, and how it does not have to use up a lot of class time.

How does the classroom teacher evaluate the writing assignments?

One concern for the mathematics teacher is the assessment of the students' written work. Not only does it in many cases require more time, but questions arise concerning what should be assessed. Research is not clear in this area—some feel that writing should be assessed on mathematical merit alone, while others feel that ignoring other aspects sends the wrong message to students. Teachers must decide the desired outcome for the writing activity before the task is assigned. At times all that is desired is for the students to express their understanding so that misconceptions can be identified, while in other situations a polished product evidencing their long term work is needed. Teachers must assess or not assess the work accordingly. We will discuss what researchers and practicing teachers have recommended, as well as supply and discuss the implementation of scoring rubrics.

Conclusion

Writing can be an effective tool in the mathematics classroom. Teachers must be willing to work together in order to find ways to use writing to its fullest potential. As a result of reviewing the readings in our reference list and sharing ideas, we hope to add to the discussion of writing in the mathematics context.

References

Bagley, T., & Gallenberger, C. (1992). Assessing students' disposition: Using journals to improve students' performance. *Mathematics Teacher, 85*, 660-63.

Davidson, D., & Pearce, D. (1988). Using writing activities to reinforce mathematics instruction. *Arithmetic Teacher, 35*, 42-45.

McIntosh, M. (1991). No time for writing in your class? *Mathematics Teacher, 84*, 423-33.

Masingila, J., & Prus-Wisniowska, E. (1996). Developing and assessing mathematical understanding in calculus through writing communication in mathematics, K-12 and beyond. In P. C. Elliott, & M. J. Kenney, (Eds.), *Communication in mathematics, K-12 and beyond. 1996 yearbook*. Reston, VA: National Council of Teachers of Mathematics (pp. 95-1040).

Mayer, J., & Hillman, S. (1996). Implementing the assessment standards for school mathematics: assessing students' thinking through writing. *Mathematics Teacher, 89*, 428-32.

Miller, L. D. (1991). Writing to learn mathematics. *Mathematics Teacher, 84*, 516-521.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (1995). *Assessment standards for school mathematics*. Reston, VA: Author.

Other Resources

Artzt, A. (1994). Integrating writing and cooperative learning in the mathematics class. *Mathematics Teacher, 87*, 80-85.

Burton, G. (1985). Writing as a way of knowing in a mathematics education class. *Arithmetic Teacher, 33,* 40-45.

Havens, L. (1989). Writing to enhance learning in general mathematics. *Mathematics Teacher, 82*, 551-554.

LeGere, A. (1991). Collaboration and writing in the mathematics classroom. *Mathematics Teacher, 84,* 166-171.

Nahrgang C. L.. & Peterson B. T. (1986). Using writing to learn mathematics. *Mathematics Teacher, 84*, 516-521.

Watson, M. (1980). Writing has a place in mathematics class. *Mathematics Teacher, 73*, 518-519.

MSaT MEd Preservice Teachers' Perceptions of Pedagogical Constructivism

Youngsun Kwak
Science Education
The Ohio State University
kwak.32@osu.edu

The purpose of my pilot study is to investigate how new Master of Education (MEd) preservice teachers construct (perceive, interpret, accept, or internalize) their own meaning of educational constructivism. Each interview lasted about 45 minutes to an hour and there were eight volunteer interviewees (5 men and 3 women).

The interview transcripts are the result of my pilot study, which was completed in the ninth week of summer quarter with MEd preservice teachers of MSAT (Mathematics, Science, and Technology Education). For MEds, that was the first quarter of their teacher education program and they were taking one of the teaching methodology courses, Logic and Psychology, which is highly focused on constructivist pedagogy. Since this interview happened in the ninth week of that course, the preservice teachers had already been introduced to constructivism and were familiar with the terminology.

Research Purpose and Questions

I attempted to investigate preservice teachers' meaning construction about constructivist pedagogy itself in terms of each individual's occupied niche in conceptual ecology and social and physical milieu. Throughout their preservice teacher education program, from the time they are first introduced to constructivism to the end of their MEd program, what impact (influence) does constructivism have on their perceptions of teaching and learning? I will use the answers to this question to make recommendations for the science teacher education program. Furthermore, through this investigation I might predict the future of constructivism, which is reflected in preservice teachers' responses to constructivism along the time line. It could be a very real impact with either positive or negative meaning, a renaming of their imagined or dreamed teaching pedagogy, or nothing different for them.

My assumption is that, in a few extremely rare cases, transitional stages could be identified in preservice teachers' pedagogy shift, influenced mainly by constructivism. Transitional stages here means that as time goes on, an individual preservice teacher could go through his own perspective elaboration processes in terms of constructivism, from person-objectivist realm to social-relativist realm in Geelan rectangular coordinators (1997). In this rare perspective change, there can be identified the internal and external causes or driving forces that enable the change, in terms of the necessity in both dimensions: the necessity of individual's personal cognitive activity and the necessity of a particular version of constructivist theory.

Another critical assumption of mine is that some of this change trials are seriously hampered by the lack of each preservice teacher's accessible background knowledge that enables them to recognize anomalies in the extant perspective as anomalies that are in need of validation or refusal.

Like many famous examples in the history of science, if an individual fails to see anomaly as anomaly he keeps expanding and building impossible hypotheses into his extant theory on false grounds to subsume more cases, explain away imminent contradictions, and ultimately avoid the crisis of paradigm change. According to Kuhn (1970), there can be three directions of response when anomaly shows up in a normal science stage: (1) try to fit in via elaborating theory such as Ptolemy's adding enormous epicycles to explain away anomalous heavenly bodies motion, (2) ignore it if it does not fit in, or (3) insert exceptions into the paradigm.

Regardless of widespread use of constructivist terminology, these preservice teachers could slip away from their preservice teacher education program without being impacted by constructivist pedagogy, which is quite counterintuitive to their own time honored transmission-absorption view of pedagogy. Alternatively, they could be rearmed with their previous pedagogy in the name of constructivism.

In sum, the study sought to answer the following questions:

1. What effects does the constructivist pedagogy taught in MEd methodology courses have on the preservice teachers' perception toward science teaching and learning? What are the different responses they make along the time line? If there is any shift in their perception of the constructivist paradigm, what is the orientation (direction)? Where are they heading and from where?

2. What are the conditions that lead to different responses to constructivist paradigm? That is, why do some preservice teachers capture and subsume constructivist pedagogy, whereas some of them ignore or remain intact in their perception? These reasons can be sought from two dimensions: one is each cognizing subject's conceptual ecology aspect; the other is the constructivist paradigm itself in terms of desire of modification or elaboration of constructivist theories.

Upon probing the first question, based on one of my assumptions that the situation in which preservice teachers encounter constructivist paradigm[1] is similar to confronting uneasy, contradictory anomaly on the condition that they can perceive anomaly as anomaly, in light of their preconceived traditional paradigm in which they have been located throughout their own schooling.

In this regard, preservice teachers' possible responses can be tracked in terms of seven basic forms of psychological response to anomalous data: (1) ignore the anomalous data, (2) reject the data, (3) exclude the data from the domain of preinstructional theory, (4) hold the data in abeyance, (5) reinterpret the data while retaining preinstructional theory; (6) reinterpret the data and make peripheral changes to preinstructional theory, and (7) accept the data and change preinstructional theory, possibly in favor of alternative theory (Chinn & Brewer, 1993). In my opinion, these categories are based on the assumption that each individual sees anomaly as anomaly.

Building upon this framework, I have reclassified seven responses to fit my study purpose. Four new categories are as follows:

First, since it is hard to differentiate whether preservice teachers ignored the constructivist paradigm (CP), or rejected CP with a wide variety of reasons for the rejection, these two categories can be recategorized as (a) no meaningful response toward CP.

Second, exclusion of CP as outside of their concerns or belonging to another domain of their lives so that CP can be compartmentalized under the theoretical, ideological domain, segregated from their everyday practices and words (e.g., it sounds good but it has nothing to do with how I act and think, it is too idealistic and theoretical); and holding CP in abeyance, with the assumption that CP will someday be articulated so that it has something to do with preservice teachers' perception (e.g., it is not time for CP yet, maybe I will think about it later; it is better for me to wait until it is well elaborated so that it can provide prescriptive, feasible, specific products for teaching and learning), these two categories can be reassigned as (b) alternative response to CP in that either of these categories implies preservice teachers' awareness of CP with unpredictable future direction of response toward CP.

Third, reinterpreting CP in their own terms which is rather incompatible with accepted meaning; and peripheral, minor modification in preservice teacher's

1 I use the term paradigm as composed of an ontology, an epistemology, and a pedagogy along with the underlying metaphors for the teacher's role.

preinstructional paradigm without fundamental change in their main theme, these two categories can be reassigned as (c) capture of CP. The difference between holding CP in abeyance and peripheral change is that, in the case of holding in abeyance, they modify CP in their own way; whereas in the case of peripheral change, they modify their preinstruction paradigm itself so that they create a niche for CP in their conceptual ecology.

Fourth, theory change can be assigned as (d) exchange for CP, which might be found in rare cases with stark revolutionary processes.

In addition, for all the categories, the perception, or position-statement shift, can be traced over time even though that could be extremely slow and steady paced. Note that in the first question my basic assumption is that the fundamental ways whereby the human collaborative society has dealt with a certain theory evolution throughout history are similar to the ways in which each individual makes a shift in perception toward that certain theory.

In so doing, I postulate there will be an evolutionary conceptual capture process rather than revolutionary conceptual exchange—in a sense, washing out the previous paradigm and replacing it with CP. As Mortimer (1995) contends, there can be found some sort of conceptual profile change while the preinstructional paradigm and CP coexist with different extent and occupying different amounts of niches in each individual's conceptual ecology.

For the second question, the conditions of a variety of responses, I will examine each individual's appropriate components of conceptual ecology that either help or block the perspective change toward CP. In this context, Chinn and Brewer (1993) enumerated factors that influence how people respond to anomalous data that can be located under the appropriate conceptual ecology component. For example, characteristics or quality of the new theory can be matched to epistemological commitments to internal consistency, in conceptual ecology in that high quality of new theory appeals more to individuals who pursue more perfect theory, which means, in a rather aesthetic sense, alternative paradigm has such characteristics as accuracy, accountability of broad scope of data, internal/external consistency, simplicity, and fruitfulness (Kuhn, as cited in Chinn & Brewer, 1993, p. 22). Some of the preservice teachers could give more weight to social constructivism than individual constructivism over the time span in their MEd program in that, in their views, social constructivism is in accord with concurrent external social needs such as multicultural education and the impact of culture; therefore, for them social constructivism has more power than individual constructivism in explaining and subsuming external (social) movement.

Upon investigating the second question, my basic framework is two sets of categories that could produce the needs of change or lack of change: one is the needs from the individual him/herself versus the needs from theory itself, resulting from lack of explanatory power; the other category is each cognizing subject's conceptual ecology versus social and physical milieu in which each person resides and is shaped as social member. The two sets of categories can be arranged along vertical and horizontal axes to form the following matrix:

	Individual demands for change	External demands for change
Personal Aspect (Individual)	(1) Within conceptual ecology components: • Metaphysical belief and concepts (Ontological beliefs) • Epistemological commitment • Anomalies (dissatisfaction)	(2) • Past experience in conceptual ecology • Social and physical milieu
Theory (Construct-ivism)	(3) Characteristics of theory in terms of conceptual ecology • Exemplars and images • Analogies and metaphors • The quality of the theory • Accuracy • Scope • Consistency • Simplicity • Fruitful as well as intelligibility	(4) Social and physical milieu • Other knowledge (or background knowledge)

References

Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science education. *Review of Educational Research, 63*(1), 1-49.

Geelan, D. R. (1997). Epistemological anarchy and the many forms of constructivism. *Science and Education, 6*(1-2), 15-28.

Kuhn, T. S. (1970). *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Matthews, M. R. (1994). *Science teaching: The role of history and philosophy of science.* New York, NY: Routledge.

Matthews, M. R. (1997). Introductory comments of philosophy and constructivism in science education, *Science and Education, 6*(1-2), 5-14.

Research Trends in Mathematics Education, 1995-1997

Hea-Jin Lee
Mathematics Education
The Ohio State University
lee.1129@osu.edu

S. Asli Özgün-Koca
Mathematics Education
The Ohio State University
koca.1@osu.edu

Teresa H. Rehner
Mathematics Education
The Ohio State University
trr1+@pitt.edu

The annual listing of *Research in Mathematics Education* (*RIME*) for many years has been published in order to provide an overview to educators and teachers about research ideas or topics in mathematics education. Before the ERIC Clearinghouse for Science, Mathematics, and Environmental Education began to publish the listings, it had been published as an issue of the *Journal for Research in Mathematics Education*, a publication of the National Council of Teachers of Mathematics. This annual listing of research in mathematics education contains annotated citations of dissertations, research papers and monographs, and journal articles focusing on the interpretation and implications of mathematics education research.

Entries in each chapter contain annotations, major and minor category codes, and grade level codes. For this research, we have taken into account the major codes, grade levels, and types of the publication in order to see the trends in research in mathematics education for the last three years. Since the databases were not available for some years or for some parts of the last two years, we created a new database from the printed listing for the items mentioned above. Moreover, since 71 codes were used in *RIME* to categorize the publications, we grouped major categories into twelve new categories: mathematics content/curriculum, achievement, assessment, student affect, teacher affect, technology, instructional techniques, social/cultural issues, teachers in general, research issues or reviews, learners in general, and theory. Grade levels were also grouped into five categories: elementary, secondary, post-secondary, K-12, and teachers.

The following tables are the results of a meta-analysis of *RIM*E. Table 1 shows the frequency in which the research has been conducted in each grade level, in what topic, and in what type of publication for three years.

Table 1: Frequencies of Research in Mathematics Education

	1995				1996				1997			
Grade	Diss	Articles	Papers	Total	Diss	Articles	Papers	Total	Diss	Articles	Papers	Total
Mathematics Content/Curriculum												
Elementary	34	37	5	76	33	18	12	63	11	34	14	59
Secondary	64	35	4	103	50	25	7	82	30	44	18	92
K-12	8	13	4	25	4	11	14	29	4	16	16	36
PostSec	50	27	6	83	36	15	2	53	26	24	6	56
Teachers	19	2	4	25	15	3	4	22	9	11	6	26
Total	175	114	23	312	138	72	39	249	80	129	60	269
Achievement												
Elementary	18	10	2	30	13	0	2	15	6	5	2	13
Secondary	41	17	8	66	27	5	3	35	8	17	1	26
K-12	3	0	3	6	1	2	8	11	2	6	4	12
PostSec	22	9	0	31	15	0	1	16	4	5	0	9
Teachers	6	1	0	7	2	3	0	5	0	0	2	2
Total	90	37	13	140	58	10	14	82	20	33	9	62
Assessment												
Elementary	2	5	0	7	7	3	2	12	2	4	3	9
Secondary	14	3	7	24	16	1	6	23	3	7	2	12
K-12	3	0	3	6	0	2	12	14	1	3	9	13
PostSec	7	5	2	14	3	0	1	4	2	6	0	8
Teachers	5	0	0	5	1	0	0	1	5	2	2	9
Total	31	13	12	56	27	6	21	54	13	22	16	51

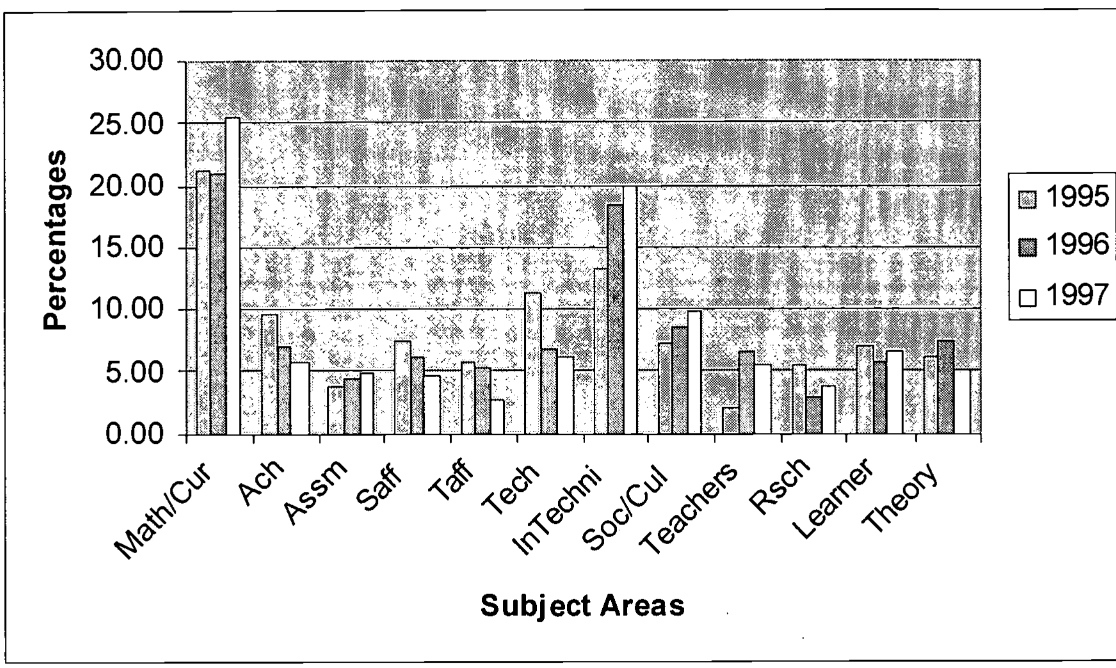
	1995	1996	1997

	1995				1996				1997			
Grade	Diss	Articles	Papers	Total	Diss	Articles	Papers	Total	Diss	Articles	Papers	Total
Student Affect												
Elementary	3	5	4	12	5	4	1	10	2	5	0	7
Secondary	28	16	9	53	22	7	1	30	5	17	1	23
K-12	0	1	2	3	0	3	1	4	0	5	2	7
PostSec	18	13	4	35	17	2	1	20	6	5	1	12
Teachers	4	1	2	7	7	1	1	9	0	1	0	1
Total	53	36	21	110	51	17	5	73	13	33	4	50
Teacher Affect												
	22	9	4	35	39	17	6	62	7	22	0	29
Technology												
Elementary	6	3	4	13	6	5	1	12	1	9	1	11
Secondary	26	8	3	37	20	10	1	31	7	7	3	17
K-12	4	3	1	8	2	3	7	12	0	1	3	4
PostSec	27	5	1	33	8	2	1	11	11	12	2	25
Teachers	9	3	0	12	11	3	1	15	1	8	0	9
Total	72	22	9	103	47	23	11	81	20	37	9	66
Instructional Techniques												
Elementary	27	30	6	63	26	20	9	55	7	37	16	60
Secondary	55	38	13	106	36	23	8	67	15	42	8	65
K-12	6	10	2	18	4	12	23	39	0	9	10	19
PostSec	18	7	5	30	14	7	1	22	11	12	2	25
Teachers	29	7	6	42	17	13	4	34	12	21	9	42
Total	135	92	32	259	97	75	45	217	45	121	45	211

	1995				1996				1997			
Grade	**Diss**	**Articles**	**Papers**	**Total**	**Diss**	**Articles**	**Papers**	**Total**	**Diss**	**Articles**	**Papers**	**Total**
Social/Cultural Factors												
Elementary	12	10	1	23	5	6	5	16	9	17	6	32
Secondary	34	28	13	75	20	10	5	35	12	27	5	44
K-12	6	7	6	19	2	13	18	33	2	17	10	29
PostSec	16	7	7	30	5	3	2	10	10	4	2	16
Teachers	5	2	1	8	4	3	2	9	3	8	5	16
Total	73	54	28	155	36	35	32	103	36	35	32	137
Teachers												
	25	16	13	54	42	22	14	78	10	34	14	58
Research												
Elementary	0	8	0	8	0	1	0	1	0	1	1	2
Secondary	0	6	1	7	2	2	0	4	0	5	5	10
K-12	1	10	13	23	1	11	9	21	0	4	11	15
PostSec	0	0	1	1	0	0	2	2	0	2	1	3
Teachers	0	1	0	1	1	6	1	8	0	4	6	10
Total	1	25	15	40	4	20	12	36	0	16	24	40
Learners												
Elementary	9	9	0	18	10	8	0	18	3	16	2	21
Secondary	14	9	3	26	17	10	1	28	8	14	1	23
K-12	1	8	1	10	1	5	1	7	1	2	3	6
PostSec	7	2	1	10	8	4	1	13	7	5	2	14
Teachers	12	2	0	14	3	1	0	4	0	1	4	5
Total	43	30	5	78	39	28	3	70	19	38	12	69

Grade	Diss	Articles	Papers	Total	Diss	Articles	Papers	Total	Diss	Articles	Papers	Total
Theory/Learning												
Elementary	20	18	1	39	10	11	3	24	3	12	0	15
Secondary	20	10	3	33	10	5	3	18	5	9	2	16
K-12	6	8	13	27	1	12	9	22	0	7	0	7
PostSec	13	7	2	22	7	4	0	11	5	7	0	12
Teachers	8	4	4	16	6	5	3	14	2	0	1	3
Total	67	47	23	137	34	37	18	89	15	35	3	53

Figure 1 : Percentages of Research Topics Conducted in 1995, 1996, and 1997



BEST COPY AVAILABLE

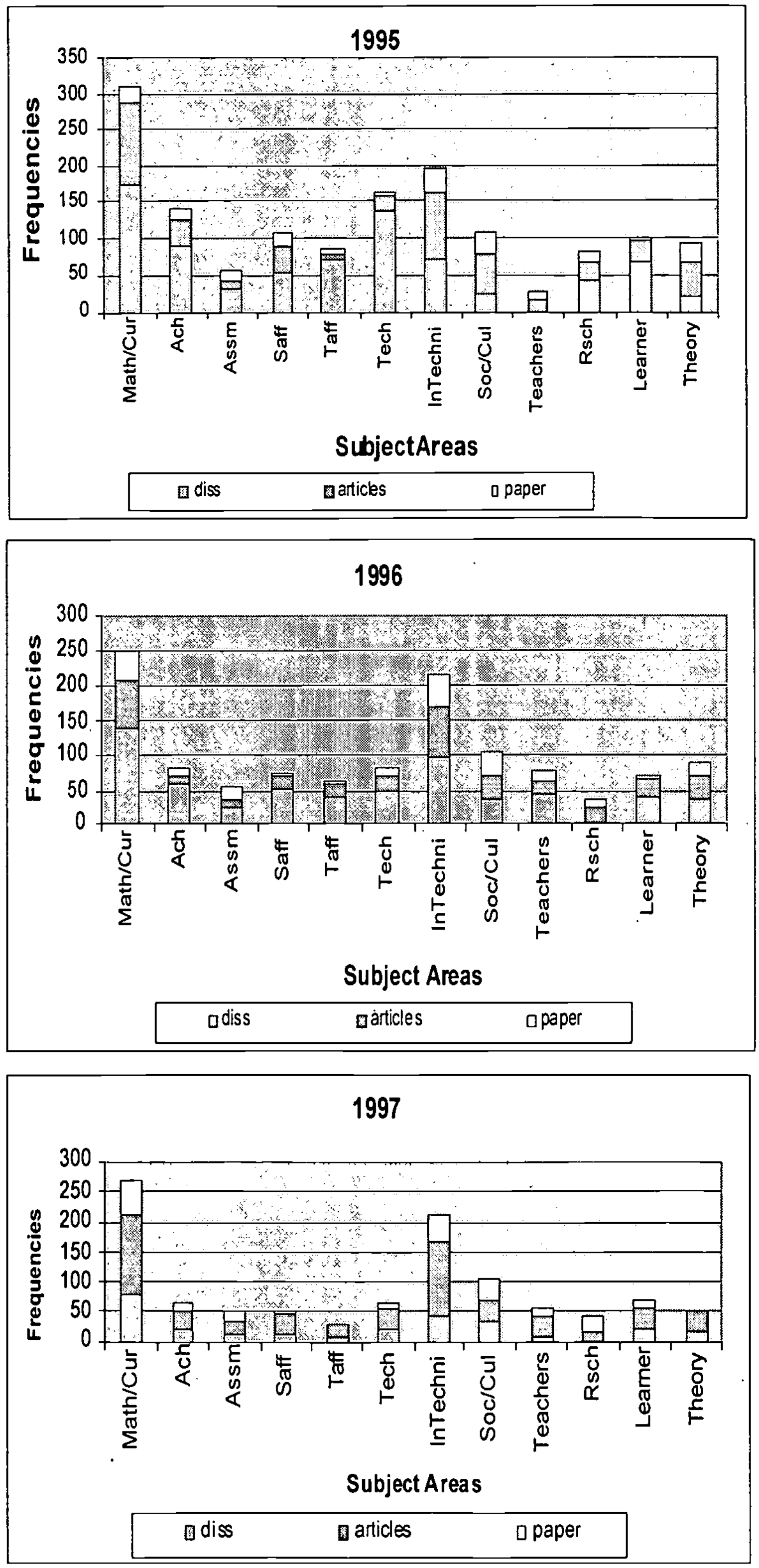


Figure 2: Frequencies of Publication Sources Within Research Topics

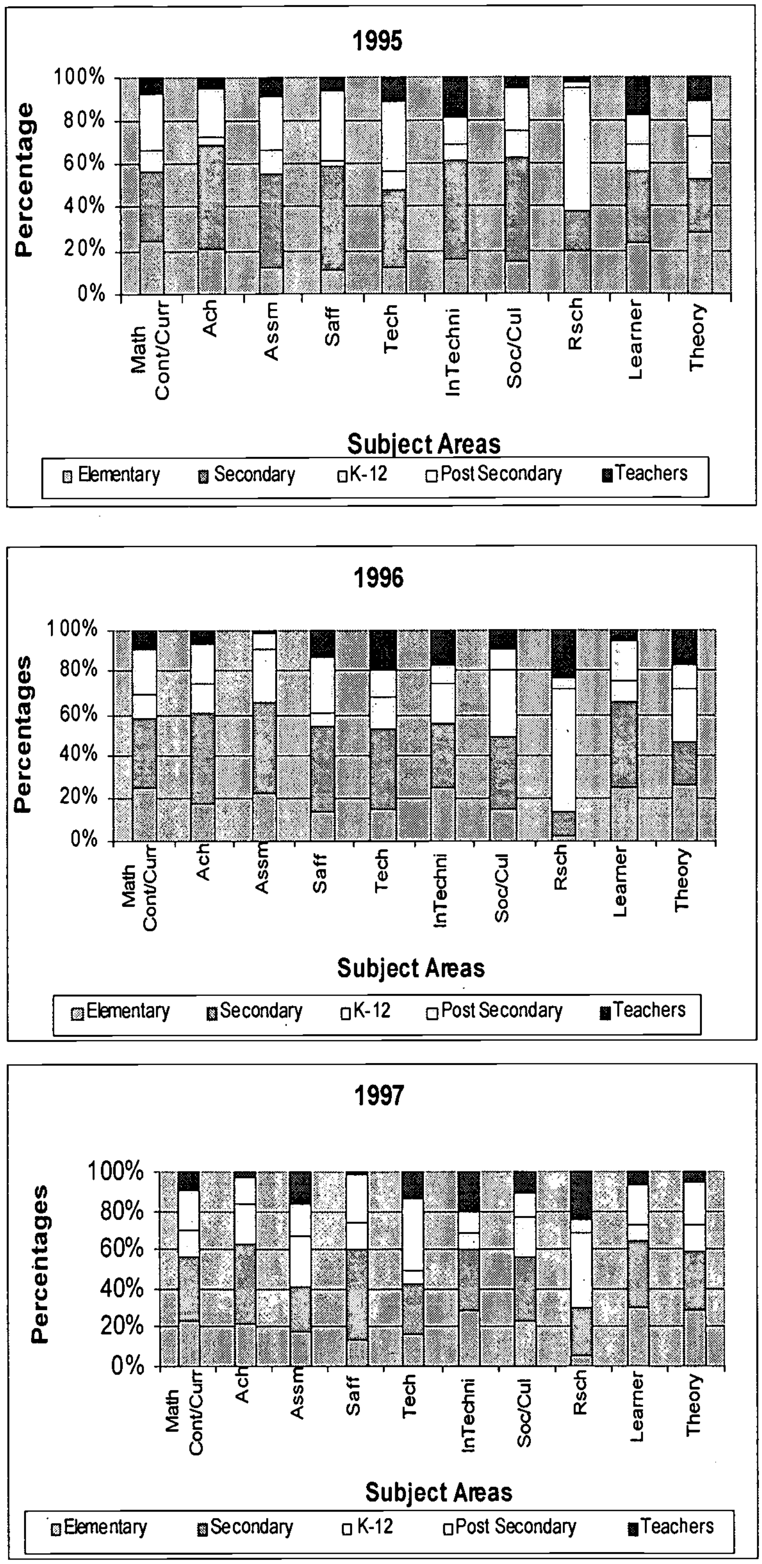


Figure 3: Grade Level Focus of Research Topics

Figure 1 shows the percentage of the research topics conducted in 1995, 1996, and 1997. This graph demonstrates the changes of interests in mathematics education over the past three years. As you can see, mathematical concepts and instructional techniques are the most researched subjects for all three years. Figure 2 displays the frequency of the sources in which research has been published for each research topic in 1995, 1996, and 1997. These figures provide information about which topics were concentrated in which type of publication. Figure 3 presents the percentage of focused grade levels in each research topic. In figure 3, we did not include two topics: teacher affect and general issues related to teachers, because of their focus on teachers.

As we mentioned at the beginning, throughout the process of analyzing *RIME*, we hoped to provide insight to students, teachers, and researchers about research ideas as well as the trends in mathematics education. In addition, we believe that this study informs educators that certain research areas and grade levels should perhaps be studied more to improve the knowledge base in mathematics education.

References

Owens, D. T., (Ed.). (1996). *Research in Mathematics Education 1995.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Owens, D. T., (Ed.). (1998). *Research in Mathematics Education 1996.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Owens, D. T., & Reed, M. K., (Eds.). (1998). *Research in Mathematics Education 1997.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

The Unique Needs and Characteristics of Monozygotic Twins as Learners

John R. Mascazine, PhD
Science Education
The Ohio State University
mascazine.1@osu.edu

Numerous studies in education and psychology have investigated the achievement or academic performance of twins (Bouchard, Lykken, McGue, Segal, & Tellegen, 1990; Segal, 1985; Wilson, 1983; Wright, 1997). However, few studies considered the questions involving how twins learn and the impact that twinship may have upon one's learning. This study addressed these issues using in-depth interviews, grounded surveys, and a reliable learning style instrument: the Dunn, Dunn, and Price Learning Style Inventory.

Four pairs of monozygotic (identical) twins participated in a series of interviews and grounded surveys. Eighteen dizygotic twin pairs and thirty-four additional monozygotic twin pairs were also given the Dunn, Dunn, and Price Learning Style Inventory. Qualitative and quantitative analytical methods were employed.

The data indicated that while monozygotic twins did share more learning style strengths in common than did dizygotic twins, both groups had many more learning style strengths that were not shared. Even among the monozygotic twins there were few shared learning style strengths and/or preferences. In learning situations twins often reported having unique preferences that differ from their twin sibling, and when these go unnoticed by their teachers, they can have negative impacts on either or both twins and their learning.

In addition to the comparison of the separate elements of the Dunn Learning Style model, additional themes emerged from the interviews and qualitative data. Five themes stood out. These themes were:

- The importance of positive early learning experiences that contributed to successful formal and informal learning situations, especially in science and technical situations.
- The role of competition between the twins and the impact such competition has upon learning, which was often a positive influence.
- The effect of twin recognition and its impact on learning, which was often reported to be a motivational or beneficial characteristic.

- The desire and need for individual recognition/identity and its impact on learning was continually cited as being important for twins as learners. Some twins reported that this was an ongoing struggle into adulthood.
- The awareness and use of individual learning style strengths by the twins in this study, was documented. Many of the twins reported knowing specific aspects of their learning style and had indeed incorporated strategies that were congruent with their styles.

Qualitative data yielded many detailed vignettes of the unique circumstances and situations that a twin may encounter in learning situations. Participants cited examples of how they had to cope with teachers, peers, or parents who expected them to behave or achieve academically. Some of the stories revealed the ways in which many people treat twins as "a unit" and how attempts to be impartial can actually be stifling to each twin's individuality. The accounts recorded led the researcher to conclude that twins have unique needs and concerns as learners, and that teachers, parents, peers, and administrators could benefit by acknowledging such needs and concerns.

This research on twins and their learning styles departed from previous studies that often over-emphasize the similarities among twins, especially monozygotic twins. This study presents evidence that twin siblings, both fraternal and identical twin siblings, often possess learning styles that are more different than alike. This was supported by qualitative and quantitative data.

References

Bouchard, T. J., Lykken, D. T., McGue, M., Segal, N. L., & Tellegen, A. (1990). Sources of human psychological difference: The Minnesota study of twins reared apart. *Science*, *250*, 223-228.

Segal, N. L. (1985). Monozygotic and dizygotic twins: A comparative analysis of mental ability profiles. *Child Development*, *56*(4), 1051-1058.

Wilson, R. S. (1983). The Louisville twin study: Developmental synchronies in behavior. *Child Development*, *54*(2), 298-316.

Wright, L. (1997). *Twins and what they tell us about who we are*. New York: John Wiley and Sons.

Science: It's a Family Thing

Judy Ridgway
Science Education
The Ohio State University
ridgway2@aol.com

This paper is the introduction to a pilot study on the effectiveness of an informal science club to increase science knowledge and reduce fear of science in both elementary school students and their parents. The club will be described in terms of leadership, sponsorship, and management. Examples of activities and an approximation of attendance will be given. Ideas will be offered about the factors affecting attendance and the effect the club has on its participants. Since this study is in its introductory phases, any feedback will be welcomed.

There exists a phobia of science that can be passed from generation to generation and can become firmly ingrained by the time students reach middle school or high school. In 1989, the parents at an elementary school, which will be referred to as Zelig Elementary in a midwestern suburb, decided to create a club to diffuse this fear. At that time, many parents felt that the science curriculum was not as strong as it should be and that it could be enriched informally. The organizers looked through the community of parents in the school and thought they could be a rich resource. Even though many of the parents on the committee through the years have had weak science backgrounds, they felt committed to providing additional science outlets for their children. Thus, what will be referred to as the Junior Scientist Club was born.

One or two parent volunteers of the Zelig Elementary School chair the committee. The chairmanship position of the Junior Scientist Club Committee became a seat on the Parent Teacher Association (PTA) board and the club has been given a comfortable budget. During the first week of school a volunteer packet is sent to every home. The packet contains a page describing the Junior Scientist Club and asks if the students want to participate, if the parents want to serve on the committee, and if they have any ideas for a meeting. There have been approximately ten parents per year who have served on the committee. The committee meets one time at the beginning of the year and selects six topics from the proposals elicited from the volunteer sheets and in the meeting. The club's goal is to have each meeting represent a different scientific field. The meetings occur both after school and on weekends to try to make it as convenient for as many families as possible.

Adults must accompany children to the meeting. There are several reasons for this. First of all, many of the activities need adult supervision because there are worksheets to be filled out, math calculations to be made, or safety factors to consider. Second, the club was not meant to be a drop-off activity for the children. Rather, because the adults are involved, the children can model their parents' interest in the activities. Third, many parents have expressed insecurities about science and their participation in the activities will hopefully make them feel more comfortable about their science abilities. It is sometimes embarrassing for the adults to be faced with topics in their children's homework that they do not understand themselves. By participating in the club activities, the parents can learn concepts in the guise of helping the children. In the end, hopefully they will understand that they do not have to have all of the answers to the children's questions, but that they possess the ability to figure them out. Lastly, each year several of the activities are away from school grounds and the adults have to provide transportation for the children. The club does not have the means and cannot accept the liability to transport the children.

An estimate of the average attendance at a Junior Scientist Club activity is about 35 people, composed of approximately 20 children and 15 adults. Some activities have had over 100 participants and others regrettably have had only about 10. The variation in the attendance has to do with time of year, day, and the amount of interest the topic garners in an elementary school population. The time of year is problematic because of sports (especially soccer and basketball) and vacations. During a few months there is no time when some cohort is not involved in athletic competition. Some children can only attend directly after school and others have parents who can only come after business hours.

The student interest factor is difficult. Some activities, like the snake presentation or the trip to a local observatory, will consistently bring large crowds. Students have had enough exposure to those topics to consider them exciting. On the other hand, the chemistry of food workshop had the lowest attendance ever recorded in Junior Scientist Club history. All three of those meetings had interesting science information, opportunities for hands-on learning, and well organized programming. It appeared that the families had a better idea of what to expect with the first two examples and could not appreciate how rich the third meeting could be.

Another factor that has a huge effect on the success of the club is the endorsement of the faculty and administration at the school. It is clear which teachers repeatedly advertise the club's programs to their students. If teachers discuss the programs in class then the students will be more apt to encourage their parents to have the family participate. The principal is also important because her endorsement on the morning announcements, at PTA meetings, and in individual conversations improves the status of the club. If the school faculty members give the club meetings importance, then the families will also.

The meetings have ranged from parent-led workshops to field trips illustrating science in action. Groups who have topics of scientific interest have also been brought to the school. Typical workshops have been about the properties of water, optics, and the physics of bridges. The presenters of the workshops are encouraged to have data sheets on which students can keep records and make calculations. Field trips have included such things as fossil hunts, a visit to an entomology lab, and tours of emergency rooms. One group, whose special interest is endangered cats, brought the animals to the school to explain how humans can affect organisms in the wild and described the diversity in the group.

It is the impression of this researcher that the club has been effective in stimulating scientific thought in both the adult and student participants. The children appear to take pride in their affiliation with a scientific group. The continued endorsement of the school faculty implies that they are seeing positive results in their students. Private discussions with the adult participants indicate that they have also learned during the club meetings and feel more comfortable discussing scientific topics. Many who claim to be weak in science continue to serve on the committee, which indicates they feel that the experience is valuable.

The research questions regarding the students', adults', and faculty's perceptions of the value of the Junior Scientist Club in terms of content and affect are going to be addressed in a survey study. By assessing all three groups a better profile will be attained. A comparison of the participants with the nonparticipants in terms of science performance will be made throughout the year to assess the effectiveness of the club in enhancing student science learning.

The Y2K Problem of U. S. School Mathematics: A Comparative View

Mourat Tchoshanov, PhD
Professor of Mathematics Education, Kostroma State University (Russia)
Visiting Scholar, The Ohio State University
tchoshanov+@osu.edu

Preamble: ***"Goal 4: U. S. students will be first in the world in science and mathematics achievement"***
(George Bush: America 2000: An Education Strategy, 1990).

The year 2000 is "just around the corner." It should be obvious that U. S. students won't be first in the world in mathematics. Moreover, in my opinion, they won't be the first in the world in mathematics even by the year 2010 either. Why?

Let me share with you some of my observations and thoughts. I hope it will be interesting for you because it is a viewpoint from the "other side" of the world. I have some expertise in comparative mathematics education: I began studying mathematics education in the U. S. in 1990, continued my research in 1994 (when I was a Fulbright Scholar at Case Western Reserve University, Cleveland, OH), and recently I began a book entitled *Mathematics Education in the U. S.* for Russian mathematics teachers.

I am confident that U. S. students will eventually be first in the world in mathematics achievement. The only question is: When?

History and Traditions of Mathematics Education in the U. S.

In the U. S., society started to pay serious attention to school mathematics in the early 60s. In Russia, however mathematics education has been a state priority from the time of Peter the Great. I could say the same about other European countries such as Switzerland, France, and some others, which have enormous and rich historical traditions in mathematics education. It is also true for some Asian countries like China and India.

Figuratively speaking, just as Russia is a *baby* in democracy, the U. S. is a *toddler* in mathematics education.

It is the same as Europe's history and tradition of men's soccer. This history puts European countries always on the top in the World Cup competition. Americans, on the other hand, just started to play soccer 10-15 years ago. I think, if someone said that the U. S. men's soccer team would win the World Cup in 2002, no one would take it seriously. By contrast, the U. S. women's soccer team is one of the best in the world.

Why? The explanation is that Americans have started to cultivate women's soccer at the *same time* as other countries. In other words, Americans are starting from the same "launching pad" as other countries in women's soccer.

The U. S. needs more time to achieve Goal 4 also in terms of psychological readiness of the society on different levels: at most, the government, school administrations, parents, and students need to make mathematics a number one priority, or at least they need to increase the expectations in mathematics achievement. American parents have high expectations for their children in sports (football, basketball, baseball, etc.), but, unfortunately, not in mathematics or even chess. If we could change the mentality of the young generation then we could expect higher achievements in mathematics from their children.

Unique Cultural and Ethnic Diversity Among U. S. Student Populations

Russia, China, Japan, and Switzerland do not have an ethnic diversity among their students' populations as does the U. S. It is quite understandable that this is one of the major factors influencing American students' mathematics achievement. This factor also has historical roots. For several generations, white Americans had priority above African Americans and Hispanics in the field of education, especially in mathematics and science. This continued during the lives of several generations of Americans. It takes several generations to solve what I would call a "generation-period problem."

Another such problem is the democratic changes in Russia, which require great efforts: Russian people must be patient before they can change the mentality of the previous generations. Similarly, the U. S. needs several generations to narrow the gap in the achievements between all groups of students in mathematics.

Better Less but Better

I was born in Turkmenistan, where 99% of the land is desert. I remember my grandfather's saying: "If you need water, my son, dig deeper."

My observation is that U. S. students are not "digging" deep enough in mathematics. Compared to Russia, the American curriculum offers more mathematics but with less depth. For example, my daughter is studying in the 6th grade of an American middle school after she has spent five years in a Russian school. She is happy to be studying here because it is much easier for her to study mathematics in the U. S.: there are no multistep proofs, no challenging homework assignments, etc. Usually, she does her homework assignment on the school bus on the way home, which takes only about 20 minutes. In Russia, she spent at least 45 minutes to get her mathematics homework done.

I am forced to teach her "extra" mathematics from a Russian textbook that we brought with us here.

American school mathematics textbooks are very attractive compared to Russian ones: They have color pictures and diagrams, historical and social sciences notes and essays, and so on. In my opinion, this distracts students' attention. Russian textbooks are black-and-white and contain only mathematics with multistep problems, complex proofs, few applications, and challenging assignments, which helps students concentrate in mathematics. I could say the same about textbooks from Japan and Korea, and they are top performing countries in the world in mathematics achievement.

One more observation I have made is something I call "lottery math": American teachers offer too many multiple-choice problems and tests that encourage problem solving by guessing. In contrast, Russian mathematics teachers mainly use constructed-response assessments. When I asked Russian teachers why they don't use multiple-choice tests, they told me: "Mathematics is not a lottery."

Mathematics is like chess. You will never win if you can think only one step ahead. You should, at least, be a "five-step thinker" in chess, and the same is true in mathematics. Unfortunately, my study shows that American schools are preparing "one-step thinkers." "Better less but better" also means the following: better to solve one complex problem by three different methods than three simple "one-step" problems with one method.

Indeed, Americans have created a number of promising projects in mathematics and science education, beginning with the excellent Manhattan Project of the 60s. However, it seems to me that there are too many of them, so that it is impossible to choose the best one, creating a national conception of mathematics education. The NCTM (National Council of Teachers of Mathematics) *Standards* is the first step in this direction.

Pay More Attention to Gifted Students

Attention to basics, does not make for a successful environment for gifted students. In Russia, there is a long educational history of working with gifted students. The movement to establish mathematics- and science-oriented schools in cooperation with universities began in Russia in the early 30s. These schools created the Junior Mathematics Academies, publishing advanced mathematics and science journals for gifted students such as *Quantum*, *Technology and Youth*, and others. Famous mathematicians were engaged in school textbook authoring; summer schools were established for gifted students to prepare them for Mathematics Olympiads, etc. This experience is still helping Russia to maintain high achievement in mathematics regardless of the current political and economic crisis.

Language, Music, and Mathematics

There are a number of important external influences on mathematics achievement (see Figure 1). Language and music are among them. I am proud that American educators value the works of the famous Russian psychologist Lev Vygotsky on the role of language in children's cognitive development. Historically, Russians have extended families: grandparents live with and take care of their grandchildren. They share their knowledge and experience with grandchildren, tell them different stories and fairy tales, answer grandchildren's challenging questions, and read books with them while their parents are at work. So, grandparents create, I would say, "an after-school extracurricular environment" in language and reading for their grandchildren. On the other hand, children have the opportunity to communicate with "rich sources" of knowledge and information, to exchange ideas, and to experience peer learning with their grandparents. All these activities have a significant influence on children's intellectual development.

There is a firm belief among Russian educators and parents that music has a great impact on the child's achievements in mathematics and science. The current research studies on this issue seem to support this belief. Until recently, Russia had a public system of music education which was established in the 20s. Usually, children begin music school at the age of 4 or 5, and then go to a regular school at the age of 6 or 7. They start to listen to and play classical music (mostly, piano and violin) at the preschool. It helps to develop children's cognitive processes and their creativity. Recently, because of an economic crisis, there was a nationwide movement to support classical music education and gifted young musicians in Russia.

"Don't Worry, be Happy"

I like this American saying very much. In Russia we often say: "There is no bad without good." Generally, school districts and educators in the U. S. are doing a great job in terms of preparing good citizens, and creating high quality living standards in American society, which is much more important than to be first in the world in mathematics achievement. In contrast, it seems that in Russia even comparatively high levels of mathematics achievement has no influence on the standard of living.

It is much more important to set realistic goals that can be achieved on schedule. I believe the most realistic goal for the U. S. is to be among the top ten countries in the world in mathematics achievement within the next decade. At that point, if U. S. mathematics educators progress with reform, I would carefully predict that by the year 2020, U. S. students will be first in the world in mathematics.

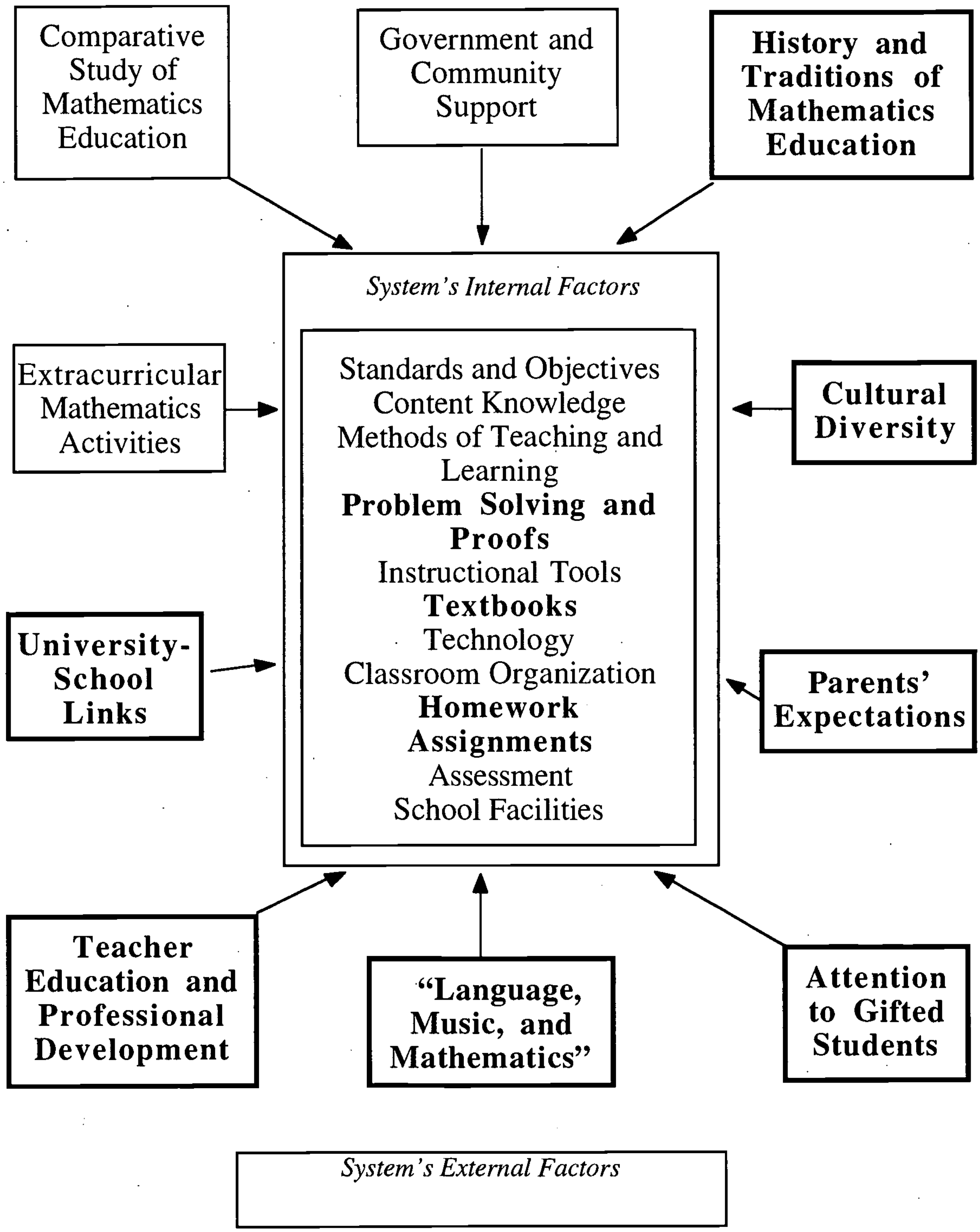


Figure 1: Internal and External Factors Influencing U. S. Mathematics Education

U. S. Contribution to the International Mathematics Education

Currently I'm observing a crisis in U. S. educational philosophy – as a whole, and the "ideology" of mathematics education, in particular. That's why U. S. educators are borrowing the ideas of European researches like Piaget, Vygotsky, and others.

A practical issue of this crisis is that there is no significant change, according to the findings of NAEP, on the level of mathematics achievement of American students during the last 20-25 years. Primarily because of the gulf between mathematics achievement of white, African American, and Hispanic students. Therefore, U. S. mathematics educators need to pay more attention to multivariable aspects of school mathematics, especially the aspect of multicultural mathematics. This aspect reflects the unique characteristic of the U. S. mathematics education. I believe this is the field where the U. S. could make a significant contribution to international mathematics education. It will also help to increase U. S. students' mathematics achievement.

On the other hand, there is, so to speak, a circulation of mathematics education pedagogical ideas between the U. S. and other countries. For instance, Russian mathematics teachers are very interested to learn from the U. S. experience in the issues of outcome-based education, implementation of hands-on technology, mathematical software, using the Internet in the teaching and learning of mathematics, utilization of the theory of multiple intelligences, alternative assessment techniques, and so on. At the same time, I am observing some interest of U. S. mathematics educators and researches in the advanced works of Russian psychologists and mathematics educators such as: A. Leontiev's theory of activity, P. Galperin, N. Talyzina's stage-by-stage development of students' mental actions, V. Davydov's theory of content generalization, V. Krutetsky's concept of students' mathematical abilities development, and others (see Figure 2). I would also suggest paying attention to the works of Russian research on the issues of "advanced" teaching and learning (L. Zankov), problem-based teaching and learning (A. Matjushkin; M. Makhmutov), and enlargement of didactic units (P. Erdniev), all of which have provided a significant improvement in the teaching and learning of Russian school mathematics.

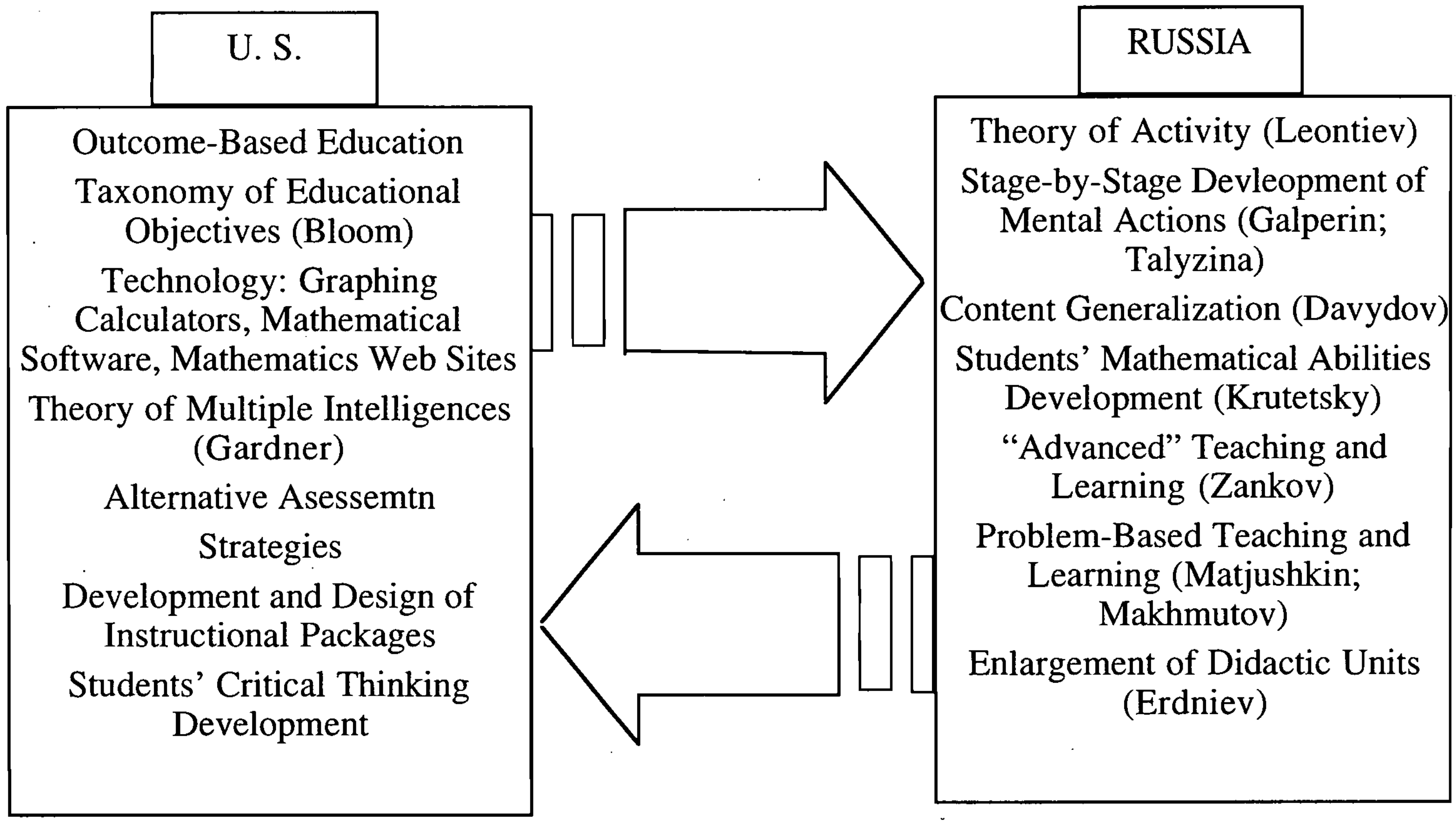


Figure 2: The Circulation of Pedagogical Ideas Between U. S. and Russian Mathematics Education

References

Davydov, V. V. (1990). *Types of generalization in instruction.* Reston, VA: NCTM.

Erdniev, P. M. (1993). *Enlargement of didactic units as an instructional technology.* Moscow: Prosveschenie (text in Russian).

Krutetsky, V. A. (1976). *The psychology of mathematical abilities of schoolchildren.* Chicago: University of Chicago Press.

Makhmoutov, M. I. (1972). *Problem-based teaching and learning: Theory and practice.* Moscow: Pedagogika (text in Russian).

Engestrom, Y., et. al., (Eds.). (1999). *Perspectives on activity theory.* Cambridge, NY: Cambridge University Press.

Galperin, P., & Talyzina, N. (1968). *Students' knowledge and skills acquisition based on the stage-by-stage development of mental actions.* Moscow: Moscow State University Press (text in Russian).

Zankov L. V. (1977). *Teaching and development.* White Plains, NY: M. E. Sharpe.

Cloning in the News:
The Popular Press as a Means for Informal Science Education

Lynda C. Titterington
Science Education
The Ohio State University
ltitter@enc.org

Suzanne Shaw Drummer
Science Education
The Ohio State University
drummer.8@osu.edu

Joyce Miller
Science Education
The Ohio State University
jmiller5@mvnc.edu

The purpose of this study was to examine the effectiveness of the popular media as a means of informal science education. Ian Wilmut's announcement (1997) that a lamb named Dolly had been cloned from an adult cell caused a furor among scientists and nonscientists alike. Throughout the year, the media bombarded the reading public with stories about the techniques, ethics, and implications of mammalian cloning. President Clinton banned the use of federal funds for cloning research. Richard Seed declared his intentions of opening a human cloning center. Soon after, scientists cloned a second lamb, Polly, from embryonic cells, and a bull calf named Buster.

Our research questions included: (1) What facts were presented in the media? (2) What facts did the general public learn about cloning from the news media? and (3) What, if any, misconceptions about cloning persisted following media coverage?

Significance

The *National Science Education Standards* (NRC, 1996) state that, "Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions," (p. 22). Other benchmarks include the ability to evaluate scientific information and to use it in personal decision making.

The popular media is the primary source of science information beyond the compulsory education years for many adults. From our previous study (Titterinton, Drummer, & Miller, 1997) we learned that the majority of adults get most of their knowledge about scientific issues from the popular media, particularly the radio news and newspapers. Even practicing scientists noted that they first heard about Dolly and other hot news items outside their field through the radio or newspapers.

The cloning of Dolly the sheep was ranked among the top ten news stories of 1997 by *People Weekly* (1997) and by *Life Magazine* (Anonymous, 1998a). CNN ranked cloning second, after the Mars Pathfinder mission. A search of *Periodical Abstracts* on Dolly yielded 399 hits. In addition to regular newspaper coverage, Dolly the cloned sheep was featured in a variety of publications from *Science* and *Nature* to *Business Weekly* and

Popular Mechanics. While the media coverage focused on the ethics and morality of human cloning, many news items included an overview of the basic science and people involved. Our research questions included: (a) Does the media accurately report scientific information? and (b) Do people read and comprehend it?

Theoretical Underpinnings

Informal education occurs in informal settings, as opposed to the formal classroom or school context. In today's American society, informal educational opportunities abound in the information provided by numerous media sources, such as television, radio, newspapers, magazines, books, movies, and the Internet. In reporting science topics, the media report and interpret science on the lay level, rather than on the more selective level of peer review at which results are reported and discussed by scientists for other scientists. Secondly, these media often bypass the established protocol for filtering the non-science from the science. Bauer (1992) depicted this process in his "Knowledge Filter" (p. 45). Frontier science is identified through proposal reviewing and grant funding processes. Then the peer review process filters out the "Mistakes," "Uninteresting Stuff," and "Fraud." The secondary literature of "Review Articles" and "Monographs" filters the science even further. The next two processes of "Textbook Science" and "Textbooks of the Future" finish this refining of science knowledge. However, there now exists a rush to report scientific breakthroughs before the competition does and even before the report appears in the peer-reviewed primary literature. This race results in "Frontier Science" being reported directly to the general public in terminology designed to inform non-scientists. These media reports may not adequately address the public's misconceptions of scientific facts and processes, and may in fact contribute to reinforcing misconceptions. An additional dimension enters when the public is brought into the "Knowledge Filter" by virtue of casting a vote in the political process of governmental funding of further scientific research as exemplified by the debate on human cloning research that occurred in the United States consequent to the reporting of Dolly the cloned sheep. Most science education research efforts have targeted science learning at the level of textbooks. A new approach is needed to examine scientific literacy, one that explores the learning that occurs in this informal context.

Within the framework of scientific literacy, it is of interest to determine the role the media play in educating the public in matters of social concern. Also, it is of interest to study the public's reception and understanding of the media information. This study reports on the media's handling of the topic of cloning, since it is frequently in the news and has probably not been specifically covered in a formal education setting. Thus, cloning and its reports in the media make it an ideal topic for exploring how the media disseminate news about "Frontier Science" and how the public perceives this information. The skepticism and the misconceptions of nonscientists are of concern as science literacy is evaluated as applied to a single topic: cloning.

Design and Procedure

A questionnaire was designed from cloning reports presented by four national news agencies: CNN, *USA Today*, *The New York Times*, and *The Christian Science Monitor*. The questionnaire was written in casual language to avoid potential artifacts that might arise from cognitive downshifting. In other words, we wanted to avoid technical language that might intimidate our participants. The first series of questions was designed to survey participants on their comfort level with science, their interest in scientific topics, and their confidence in the validity of news reports. The second series of questions, a multiple-choice, five item quiz over well-publicized facts about cloning, asked participants to identify Ian Wilmut, Richard Seed, and the country in which Dolly was cloned. The third group of questions presented a series of statements about cloning and asked participants to score them on four criteria: (1) I've read this and it's true; (2) I haven't heard this, but it sounds likely; (3) I've heard this, but I doubt if it could be true; and (4) You've gotta be kidding! The final group of questions was designed to address some of the commonly held misconceptions about cloning. Participants were asked to predict the outcome of a series of scenarios in which people had been cloned.

Findings

Although the news media concentrated on the ethics of cloning, the basic information was available to the reading public. The following facts were presented consistently: Dolly the sheep was the first mammal ever cloned from an adult cell; the technique used was cell fusion; and the success rate was 3.4%. Although the technique has not been repeated in sheep, a second sheep, Polly, has been cloned from an embryonic cell in which human genes have been inserted (Schrof, 1998). Other cloned animals include Gene, a bull calf cloned from fetal cells, and a colony of mice that was cloned via microinjection. A sample tutorial from CNN describes the technique:

> Here's a short course on how Dolly came about:
> Scientists took a cell from an adult sheep's udder. They took an unfertilized egg from a second sheep, and removed the part that contains its genetic code. Next, the cell and the egg were zapped with electricity to combine them. The egg began dividing as a fertilized egg would divide, and became an embryo. The embryo was implanted in a third sheep, a surrogate mother, that gave birth to Dolly. Aside from being genetically identical to the sheep that donated the udder cell, Dolly seems normal in every way. (CNN, 1997)

In addition to the animals and the techniques, other names in the news included Ian Wilmut and Richard Seed. Wilmut, an embryologist from the Roslyn Institute in the United Kingdom, cloned Dolly (Wilmut, et al, 1997) as part of an ongoing research project to breed a strain of mammals that would secrete beneficial compounds into their milk. While Wilmut has stated that he is opposed to cloning humans, physicist Richard Seed has proposed to open a human cloning clinic (Cole, 1999; Nash, 1998), prompting a rush of legislation to impose a moratorium on cloning research. Other scientists point out that cloning isn't so different than having identical twins, except that one is born much later (Peter Caws as cited in Marquand, 1998; Silver, 1997).

Silver (1997) identifies several commonly held misconceptions about cloning. The first comes from the popular usage of a clone that refers to an inferior copy of the original. This definition leads many people to believe that a clone will inherit not just the parent's original genetic material, but also his or her personality or consciousness. This misconception omits the contribution that environmental factors such as experience, education, and human relationships have on the formation of personality. A second misconception is that the newly cloned organism will be an adult copy of the original donor. Real cloning, however, takes place at the cellular level and the immediate product of cloning is simply a diploid egg cell that has the potential to develop into a fetus. The third misconception is that test tube babies develop in an incubator, instead of a womb. Lastly, many people believe that cloning technology can be used to create a slave race or an army of particularly fierce soldiers. This scenario does not consider that the slow rate of human growth and development would make these schemes far too expensive to consider.

Based on a survey of convenience, many people felt that they had at least some knowledge of cloning, although they did not feel that the media was explaining the issue very well or very accurately. When asked specific questions concerning the cloning of Dolly the sheep, approximately 45% of the participants were able to answer eight of twelve questions correctly. Almost all participants were unable to identify correct and incorrect headlines from 1997. Finally, approximately 50-54% of those surveyed adhered to one or more commonly held misconceptions about cloning.

References

Anonymous. (1997, December 29). Dolly. *People Weekly, 48*, 110-111.

Anonymous. (1998a, January). 1997: The year in pictures. *Life, 21*, 24-66.

Anonymous. (1998b, January 12). The news in brief. *The Christian Science Monitor.*

Anonymous. (1998c, January 21). The news in brief. *The Christian Science Monitor.*

Anonymous. (1998d, February 9). Some doubts about Dolly. *Newsweek, 131*, 6.

Bauer, H. H. (1992). *Scientific Literacy and the Myth of the Scientific Method.* University of Illinois Press: Urbana, IL.

Carey, J. (1998, March 2). Don't ban cloning. Don't ban cloning. *Business Week*, 44.

CNN. (1997). *A sheep cloning how-to, more or less.*

Cole, W. (1999, January 11). Seed of controversy. *Time*, 77.

Fillon, M. (March, 1998). Natural born factories. *Popular Mechanics, 175*, 66-68.

Marquand, R. (1998). Cloning bolts ahead...toward people? *The Christian Science Monitor.*

Nash, J. M. (1998, January 19). Cloning's Kevorkian. *Time*, 58.

National Research Council. (1996). *The National Science Education Standards.* Washington, DC: National Academy Press.

Silver, L. M. (1997). *Remaking Eden: Cloning and beyond in a brave new world.* New York: Avon Books.

Schrof, J. M. (1998, February 2). Custom cows, human clones? *U. S. News and World Report, 124*, 36.

Titterington, L., Drummer, S., and Miller, J. (1999). Cloning in the news: The popular media as a vehicle for informal science education. Paper presented at the National Association for Research in Science Teaching, Boston, MA.

Wilmut, I., Schnieke, A. E., Mcwhir, J., Kind, A. J., & Campbell, K. H. S. (1997). Viable offspring derived from fetal and adult mammalian cells. *Nature, 385*(6619), 810-813.

Analyzing Student-Generated Representations of Complex Data Sets

R. Paul Vellom
Science Education
The Ohio State University
vellom.1@osu.edu

One powerful set of tools that scientists, and in particular those who study environmental systems, use to help them understand complex natural phenomena is coherent representations. These representations illustrate or depict sometimes vast arrays of numerical data in ways that allow its use—to show relationships, and to further processes of inquiry that enable greater understanding of the dynamic forces at work in natural systems. Quite often, the creation of meaningful (and therefore useful) representations goes hand-in-hand with other science processes: hypothesizing, experimentally testing hypotheses, engaging in validation of data within scientific working groups or communities, and reporting or explaining findings so that others may use them.

In instructional settings, representations may play a number of roles in both mathematics and science instruction, as well as instruction in other subjects. Commonly, the idea of *representation* is reduced to mean *graph* or *diagram*. In fact, this reduction is represented in the students' work in this study. Yet, broadly conceived, representations go beyond pencil-and-paper creations to include a wide range of products and activities that provide a momentary capture of a set of ideas or relationships, or in some way make intelligible an array of numerical data, often tabular in form. For the purposes of this study, *representation* is defined as a graphical embodiment of tabular data.

Objectives

This study analyzed student-generated graphic representations produced by groups of science-capable high school students during an intensive summer training institute as part of the *EarthVision 2000* project. These representations were produced by the students on day one of the institute in response to a task asking them to graph or otherwise pictorially represent a data set with six variables. The variables in this case were personal information and measurements taken from the participants in the institute. Using students' personal information such as height, age, hair color, and eye color as data is a common practice in many biology and general science classrooms today.

This study was focused by the following questions:

(1) When students are asked to represent complex data sets, what are some common features of the products? How do these products compare with those experts might make?

(2) In the process of making these representations, what kinds of decisions do students make in order to manage the complexity of the data? On what bases are these decisions made, and how fruitful are the results?

The 12 students in this study were selected by their teachers (who also participated in the study and project) as *student interns* who would assist them with implementation of model-based instruction in the classroom during the school year following the summer institute. In general, these students were science-capable, as demonstrated by past performance, and were respected by their peers as approachable and knowledgeable. The participants worked in self-selected groups based on their schools. Most of the groups were mixed-gender, and members did not know each other well before coming to the institute.

Methods and Data Sources

Data collection occurred during the first week of the project's two-week summer institute. Data in the form of videotapes and copies of student work were collected during the institute, as well as handouts, institute schedules, and related resource materials. Analysis included examination of the representations themselves for features and complexity, and transcription of videotaped presentations of these graphics during the institute. Videotapes were viewed in conjunction with student work, which allowed examination of representations in context and enabled a closer capture on students' thinking as they created and presented them. Preliminary analyses presented here will lead to follow-up interviews with student participants, in which we explore how the students thought about complex data sets, and the kinds of choices they made to manage the task of representing the data.

The Task: Gather Data and Create a Representation

The students were asked to collect personal data from each other, in whatever way they deemed appropriate, and then to create a representation of it. Graph paper, colored pencils, and crayons were supplied. The data was to consist of: name, birthday (and thus, age), height, grade in school, eye color.

Parameters for collecting data were not given, nor were instructions on recording, seeking verification, or whether some data had to be collected by measurement or direct observation (for instance, height and eye color could have been self-reported or they might have been determined by direct observation, and this was left up to the students). Most students were observed collecting name, birthday, grade, and eye color by reporting, although some examination of eyes was seen. Meter sticks were provided, and students worked out a system for measuring each other's height and reporting the results.

Once data was collected, students were seated in self-selected groups of three to five, but no requirement to *work together* was given. We observed that some groups talked about what they were doing, and some did not. Presented representations showed that few students actually worked together to create graphs of the data. Rather, most worked *parallel* to each other, within proximity in terms of both space and completion of the task. In most groups, each person created a graph and presented it separately. As soon as all students were done with their graphs, they were asked to present to the group in turn, explaining what they had created.

Data and Findings

For the purposes of illustration, graphic representations created by two students, Gail and Brian (pseudonyms) will be shown and examined. These two students were selected because their presentation was audible on the videotapes, because they represent nearly the maximum range of response across all students, and because they were seated in the same group for task 1 and were on the same team for the final presentation.

Four of the six student groups made a series of two-dimensional (x-y axis or pie) graphs to represent the data, with one or two variables in each representation. Thus, in effect, these students did not represent the entire data set, but broke it into subsets for graphing. The set of graphs included bar graphs, line graphs, pie graphs, and one pictogram. Not all of the representations were "correct," in terms of errors of scale, inappropriate kinds of graphs (line) for the data shown, or inaccurate representations.

Gail's initial graph, shown in Figure 1, is a bar graph in horizontal orientation, with names of individuals down the y-axis, and birth months across the x-axis. It represents a good graph in that the scales are consistent, axes are labeled, and the bars are shaded. However, bar graphs are used when the length of the bar indicates an amount or quantity; thus, the graph is used to show relationships between differing amounts or quantities. The use of a bar graph here would be judged inappropriate by most mathematicians and scientists, because the length of the bar does not indicate a quantity or amount, but instead membership in one of a number of discrete categories. Similarly, the completed graph does not elucidate relationships (though a reader may be able to find this information), such as how many of the students were born in a particular month.

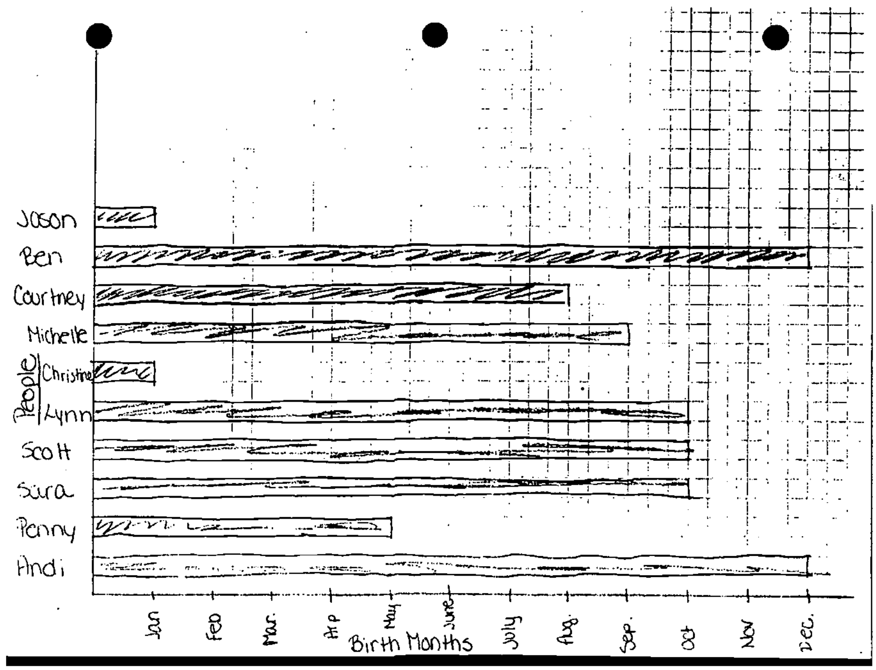


Figure 1: Gail's Initial Graph

During her presentation, Gail appeared shy, self-conscious, and unwilling to say much about her graph or its creation. She did not indicate a willingness to say what she thought about her graph, or to defend it. She seemed uncomfortable talking in front of the group. From her presentation alone, definite statements about her abilities and/or understandings related to data and representations cannot be made.

Brian's initial graph (Figure 3) was a bar graph in the same orientation, with each participants' name along the y-axis and height (in centimeters) along the x-axis. This is an appropriate construction, where the length of each bar indicates the height of the participant. One can easily tell who was tallest, next tallest, shortest; thus, relationships are shown, as well as data points for each individual.

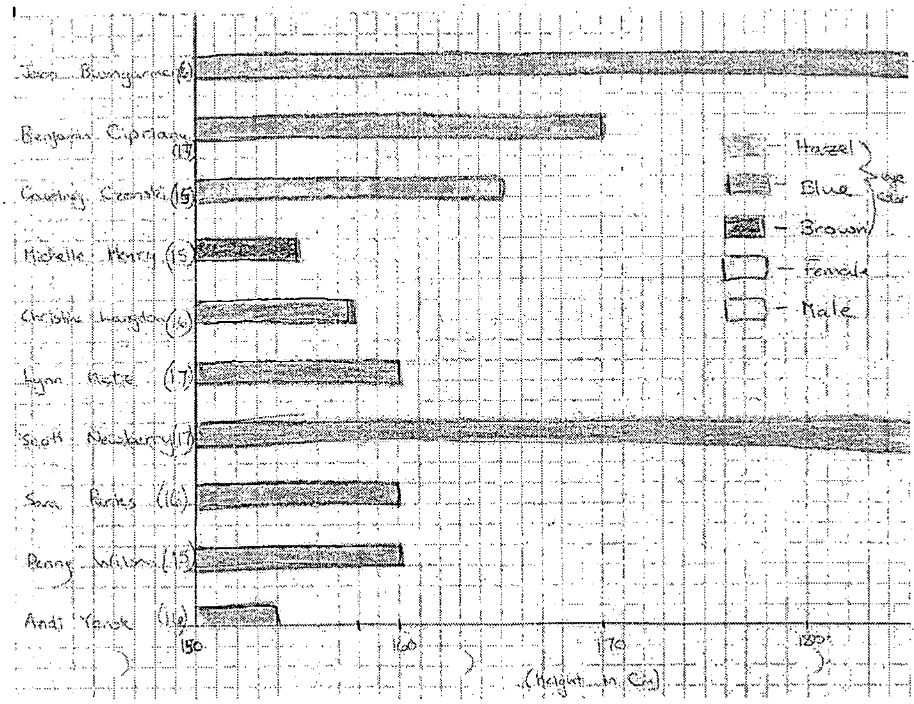


Figure 3: Brian's Initial Graph

Brian also layered other data into the bar graph. He listed each participant's age (a value he calculated using birth date) next to the name on the y-axis. In doing so, he included this data, but did not do so in a way that made seeing relationships easy. He also used color in two other layers: he shaded each bar to indicate eye color, and he outlined each bar to indicate gender. However, when subsets are important in bar graph displays, the bars are usually grouped by subset; this means that only one additional variable is possible. Brian's layering didn't include this grouping for either of these variables, but his use of color did make it possible for the reader to interpret the frequency of these variables relatively easily. Essentially, while his display of these variables was unconventional, it worked in some ways.

During his presentation, Brian revealed that he had made a decision that one set of data, grade in school, was not relevant. He also truncated age to the year. These kinds of decisions about data were common among the larger group, and apparently were made whenever reasons seemed to dictate. However, we did not see evidence that the students either did or did not understand how scientists make these decisions. It was clear that Brian made these decisions on the basis of his judgments about the value of the data. He didn't see the grade level as "relevant to anything that we really had to find out here," and he did not provide a rationale for truncating the age data.

Notes on Analysis of Representations

Analysis of a class set of graphic representations can be complex, particularly when the set is large. In this case, 10 representations comprised the set, and even with this number, care and caution should be the watchwords. In my analysis, I sought to figure out what each student was thinking as a part of analysis. So, while it is tempting to just look at the paper-and-pencil graphs as representing understanding and thought, one must remember that they were created as a part of a process, and looking at the process itself can reveal much that may not be apparent on the page. For more rationale and thinking along these lines, see Greeno and Hall (1997).

I began my examination of the graphs by laying them out side-by side on a table, so that I could see the set as a whole. I noted first the gross features: the kinds of graphs in the set (pie graphs, line graphs, bar graphs, pictographs) and the relative frequency of each. Next, I looked at each graph for a number of "standard features" that I used in my past life as a biology teacher. They are:

1. axes labeled to indicate variables
2. consistent scale on each axis
3. scale appropriate for range of data
4. data entered on graph in consistent way
5. type of graph appropriate for variables chosen
6. meaningful relationship represented on graph

Note that these features include some (numbers 1 and 2) that are essentially yes/no judgments based on face value, and some (numbers 4, 5, and 6) that depend on the reader's understanding of data and graphing. In examining graphs for this latter set of features, we move increasingly into more subjective evaluations of what we see, and considerable care and attention to detail must be exercised at this stage. Checking and rechecking, comparing, looking for unique approaches—these are common and necessary during analysis.

From examination of my notes on how each graph met these criteria, I was led to make some summary judgments about the nature of each graph and its effectiveness in representing some or all of the data in a meaningful way. I then turned to the videotape of students creating their graphs and presenting them, to try to get a better picture.

I discovered that the videotape of students working in groups was not very useful for figuring out what occurred on an individual basis because the camera focused on one group at a time to the exclusion of other groups. Audio quality was also a problem; I was able to make out some of what was said, but only in the groups closest to the camera, and often only when the speaker was facing the camera. Still, I was able to make the judgment that most students worked parallel to each other; I was also able to observe significant segments of several minutes' duration showing some individuals—among them Brian and Gail—producing their graphs.

Once presentations started, the tape became more useful, as students spoke in turn, and virtually all of the talk between presentations was in turn and initiated by the instructor. I viewed all of the presentations, taking notes on each and also stopping the tape to look at each graph as it was presented. These notes included language the students used to describe and explain what they were doing as well as other statements. After viewing all of the presentations, I was able to decide which of the representations would be used in conference presentations and related papers, and thus which segments of videotape should be transcribed. I then transcribed these segments, referring to other segments where inference led me. Again, I wanted to paint as complete a picture as possible, and I understood that well-chosen examples were important in both speaking and writing about the data set.

The decisions related to which representations should be included in reports were among the most difficult to make. In selecting Brian and Gail, I was acutely aware that I was choosing to show a "correct" male and an "incorrect" female, in terms of what they had done on the representation task. I debated whether to remove names, or to shield gender with androgynous names. In the end, I rejected both of these options; I didn't want to distract from the real issues here, and was willing to discuss the choice with my audience. I am sufficiently aware of the entire set of 10 graphs to reflect that (1) the institute itself had eight female and two male participants on this day; (2) the females' constructions were comparable in range to those of the males; and (3) statements about competence relative to gender are hard to make on such a small sample, but on an intuitive level, I did not find significant gender indications in examining the representations.

In selecting Brian and Gail as examples, I was interested in demonstrating to the viewer/reader the range of performance on this task. I wanted to open the reader's eyes to see what I saw, without enumerating all of the criteria. In making this choice, I laid out much of the ground on which I wanted to walk in conference presentations and papers. The choice was initially 4 of the 10 graphs; when I finished discussion of two of the four, I realized that the other two did not add much. I revised the analysis and discussion accordingly.

It is my hope that these notes will be helpful in the readers' thinking about analysis of concrete representations. Remember the context!

Reference

Greeno, J. G., & Hall, R. P. (1997). Practicing representation: Learning with and without representational forms. *Phi Delta Kappan, 78*, 361-367.

Teaching to the Imagination: How to Integrate Science, Mathematics, and Technology Within a Humanities Curriculum

Steve Winters
Science Education
The Ohio State University
nashwin@bright.net

A Synopsis of "Teaching to the imagination: How to integrate within a humanities curriculum—or 'it don't mean a thing if ain't got that swing.'" In *A Certain World—A Commonplace Book*, W. H. Auden writes beautifully about his entry into the world of language and poetry:

> Most of what I know about the writing of poetry, or at least the kind I am interested in writing, I discovered long before I took an interest in poetry itself.
>
> Between the ages of six and twelve I spent a great many of my waking hours in the fabrication of a private secondary sacred world, the basic elements of which were (a) a limestone landscape mainly derived from the Pennine Moors in the North of England, and (b) an industry—lead mining.
>
> It is no doubt psychologically significant that my sacred world was autistic, that is to say, I had no wish to share it with others nor could I have done so. However, though constructed and inhabited by myself alone, I needed the help of others, my parents in particular, in collecting the materials; others had to procure for me the necessary textbooks on geology and machinery, maps, catalogues, guidebooks, and photographs, and, when occasion offered, take me down real mines, tasks they performed with unfailing patience and generosity. From this activity, I learned principles which I was later to find applied to all artistic creation.

I quote Auden at some length because I want to use his idea of the "private, secondary, and sacred world" to illustrate how the power of metaphor can serve not only as a model of how we learn but as a model of education itself. Auden's world is both mythical (or metaphorical) and real. Indeed, it would seem the more mythical, the more real. How can this be?

My talk will elaborate on this paradox—both philosophically and historically—but it will not resolve it. Instead, I hope to show how, as teachers, we must learn to work in the twilight zone of the imagined and real; how we must move in the half light and not stumble; how we must lead students into a world that is interesting and safe to be in—not unlike the limestone landscapes and lead mines of Auden's youth—but never forgetting that the last step is to assist the student to emerge from her vividly "real" but imagined world having a clearer vision than before she entered it.

Working in the twilight of Auden's paradox means several things—all of which I believe are important to the practice of teaching.

First, education is a "thing" unto itself: it cannot be reduced to an "ism." John Dewey (among many others) rails against the proliferation of "isms" in our modern world. Unfortunately, education has been no less successful than science and the humanities in avoiding the disintegration (and devolution) of its ideas into ideology and technique. As Dewey did in his lifetime, we must promote and defend education as a philosophy, not as the technology or engineering of information delivery. The latter are tools for propagandists; the former is enlightenment, and is the domain of educators.

Second, all reflective teachers—whether they work in schools that are the refuge from the real or in the "real" worlds of science, scholarship, the arts, or the building crafts—should see their practice as a metaphor or as a model for knowing the world in the widest possible sense. Metaphors engage the imagination and make us see. We should use metaphor not only to teach the content of our lessons but also to explain how we teach that content.

Finally, no one can tell where learning or education may lead. No one—not even Auden himself—could tell where his juvenile studies and fantasies about limestone landscapes and lead mining would lead. Teaching any and all students involves this same sensitivity to and trust in the inner visions of our students. We should respect their "native" imaginative languages. In the world of the imagination, all of our mental faculties are challenged, and it is here where the humanities (particularly literature, poetry, and history) are our guides.

Indeed, no one can *really* tell teachers how to teach. I frequently use a music metaphor to capture the sound and rhythm of the teaching and learning experience: teaching, like a musical ear, is a gift that is artfully and painstakingly developed—not a skill that can be mechanically acquired through training. Moreover, the practice of one's art of teaching is stubbornly personal, even idiosyncratic. What is "good" is frequently what "works" and what works most often is deemed "best." There are no (nor should there be any) monolithic or dogmatic schools of education. In the world of teaching and learning, I like to think—as Duke Ellington put it— "if it sounds good, it is good," and that "it don't mean a thing if it ain't got that swing."

References

Auden, W. H. (1970). *A certain world: A commonplace book.* New York: Viking Press.

Dewey, J. (1938). *Education and experience.* New York: Collier.

Poster Presentations

MSaT in the Educational System of Korea

Hea-Jin Lee
Mathematics Education
The Ohio State University
lee.1129@osu.edu

Hyonyong Lee
Science Education
The Ohio State University
lee.1503@osu.edu

Kyungsuk Park
Technology Education
The Ohio State University
park.392@osu.edu

The Republic of Korea, founded in 1948, is a democratic state with a five thousand year history. According to the written history of Korea, "Korean formal education began with the foundation of Taehak (Great School) in the year 372" (Ministry of Education [MOE], 1998, p. 6). Korean modern schools were established by Christian missionaries and patriotic leaders at the end of 19th century and have grown continuously since then. For example, a report of the Third International Mathematics and Science Study (TIMSS), conducted in 1995, shows a relatively effective educational system in Korea.

> In mathematics, fourth-grade students in 7 countries outperform [U. S.] fourth graders (Singapore, Korea, Japan, Hong Kong, the Netherlands, the Czech Republic, and Austria). ... In science, students in only one country-Korea-outperform U. S. fourth graders. Student performance in 5 countries is not significantly different from ours (Japan, Austria, Australia, the Netherlands, and the Czech Republic), ... (U. S. Department of Education, 1997, p. 19)

In this paper, we will discuss the overall educational system, curriculum, and teacher education in Korea in terms of mathematics, science, and technology education (MSaT).

Education in Korea

School System

Korea has a centralized system controlled by the Ministry of Education (MOE). Local offices of education at 15 districts (9 provinces and 6 metropolitan areas) are mainly controlled by the MOE. Korea has used a linear school system of the 6-3-3-4 type: elementary (6 years), middle school (3), high school (3), university (4) or junior college (3) since 1949 (MOE, 1998).

Curriculum

All schools in Korea have to follow a national curriculum set by the MOE. There have been six revisions of the national curriculum since 1948. The current 6th curriculum for elementary and middle school was implemented in 1995. The new 7th national curriculum will be implemented for all grades from March 2000 through March 2004 (MOE, 1999).

Textbooks

In elementary schools, students have to use a national textbook published by the MOE for each grade level. However, the government policy of secondary school textbooks was changed from "a government authorized system" to "a government approved system." The textbooks for MSaT at the secondary level are approved by the Ministry of Education if their contents meet the national curriculum guidelines and standards. Secondary school MSaT textbooks are usually authored by university professors teamed with MSaT teachers (MOE, 1997c).

MSaT Curriculum

In this section, mathematics, science, and technology in the current 6th curriculum will be discussed. Table 1 illustrates the minimum number of total instructional hours by MSaT subjects and grade level per year.

Table 1. The 6th National Curriculum (Modified from MOE, 1998)

Schools Grades Subjects	Elementary School						Middle School			High School		
	1	2	3	4	5	6	7	8	9	10	11	12
Mathematics	120	136	136	136	170	170	136	136	136	*		
Science	120	136	102	136	136	136	136	136	136	*		
Technology	-	-	34	34	34	34	34	68	68	*		
	(Practical Arts)						(Technology-Industry)					

*MSaT curriculum in high school (See poster for details)

Elementary School: 1) One instructional hour covers 40 minutes. 2) The above table shows the minimum number of total instructional hours by subject and grade level during 34 school weeks per year except in grade 1, where the standard number of school weeks is 30. 3) In the case of grade 1, 70 hours among the total 790 instructional hours should be allocated to an orientation program in March.

Middle School: 1) One instructional hour covers 45 minutes. 2) The above table shows the minimum number of total instructional hours by subject and grade level, during 34 school weeks per year.

High School: 1) The academic high school aiming at general education may establish tracks such as humanities and social sciences track, natural sciences track, vocational track, and other tracks, if necessary in the 2nd and above, in order to provide linkage of the school courses to students' future career. Transfer to the vocational track is permitted even in grade 3. 2) The figures in parentheses are the number of units to be completed, and on unit means the amount of school learning undertaken by a 50 minute instruction period per week for one semester, which is equivalent to 17 weeks. 3) Only general subjects are introduced because specialized subjects are too complicated.

Mathematics is dealt with a compulsory and core subject at all levels. The current curriculum is designed to improve basic mathematical skills, problem solving skills, and the application of mathematics concepts (MOE, 1997b).

Science is also a compulsory and core subject at all levels. The science curriculum emphasizes the development of scientific thinking skills, creative problem solving abilities, and scientific knowledge and methods (MOE, 1997a).

Technology is a compulsory subject only in middle school. The technology education curriculum provides experiences that help students understand the basec concepts of technology and industry (MOE, 1994).

Teacher Education in MSaT

Teacher education is offered by two certification programs: a four-year degree program in an education college or a teaching certificate program offered at a general college or university. The teaching certificate programs in general departments offer teacher education courses to students who qualify in the top 30%. In considering the uniqueness and the professionalism of the teaching profession, applicants to the colleges of education take an aptitude test and humanities test as well as the scholastic achievement test and the high school achievement score (MOE, 1997c).

The required credit hours to graduate from a college of education ranges from 130 to 150: the liberal arts 20%, the major field 60%, and the electives 20%. The major field includes the study of curriculum, pedagogy of subjects, general pedagogy, and practice teaching. That is, secondary science, mathematics, and technology education teachers take as many as 20 courses in an area of specialty: seven or more courses in educational theory, two courses in specific mathematics, science, and technology education teaching methods, and a four-week student teaching practicum. The teaching certificate is conferred without additional testing to students who have finished the required courses.

The employment test for public schools consists of two types of tests. First is a test on pedagogy (30%) and the major field (70%). Those who pass this test then take a second essay test and complete an interview. The reported rate of success on these tests is around 20% (MOE, 1997c).

Inservice teacher training programs are designed to improve educational expertise and quality, which include training for certificates, general training, professional job training, special training, and overseas training (MOE, 1997c).

Conclusion

As we have seen, it is not easy to identify an integrated MSaT curriculum in Korea. The primary reasons impeding the development of an integrated curriculum is the lack of teacher preparation programs as well as the difference in time and credit requirements for each subject area at each level.

However, there is a movement toward an integrated curriculum in Korea. The integrated curriculum known as *Science-Technology-Society* (*STS*) is a part of this endeavor. *STS* has been adopted in the current curriculum in Korea. Therefore, science and technology education content are reflected in societal issues (MOE, 1997a).

The new seventh national curriculum will be implemented in 2000, and will fundamentally change the structure of the Korean educational system. It is hoped that this educational reform will solve current education problems and will contribute to the development of Korean education in the 21st century.

References

Ministry of Education (MOE). (1994). *Technology and industry curriculum in the middle school* (written in Korean). Seoul, Korea: Author.

Ministry of Education (MOE). (1997a). *Science curriculum* (written in Korean). Seoul, Korea: Author.

Ministry of Education (MOE). (1997b). *Mathematics curriculum* (written in Korean). Seoul, Korea: Author.

Ministry of Education (MOE). (1997c). *Education in Korea: 1997-1998.* Seoul, Korea: Author.

Ministry of Education (MOE). (1998). *Education in Korea: 1998-1999.* Seoul, Korea: Author.

Ministry of Education (MOE). (1999). *The school curriculum of Republic of Korea* [Online]. Available: http://www.moe.go.kr/ [1999, March 13].

U. S. Department of Education. (1997). *Pursuing excellence: A study of U. S. fourth-grade mathematics and science*, NCES 97-255, Washington, DC: U. S. Government Printing Office.

A Comparison of Middle School Technology Education Curriculum Between Korea and the United States

Kyungsuk Park
Technology Education
The Ohio State University
park.392@osu.edu

Many countries in the world have adopted technology education as part of the general education for all students throughout their middle school years. In Korea, technology education has been provided as a compulsory subject since 1969. On the other hand, technology education in the United States has traditionally been an elective subject.

This paper will explain the differences and similarities of technology education in the middle school between Korea and the U. S.

History of Technology Education

Korea

Middle school technology education in Korea has been changed by several revisions of curriculum. As can be seen in Table 1, there are many characteristics that have changed.

Table 1. Changes in subject name, time periods, and target students of middle school technology education (Modified from Yi, 1997)

Time period	Name of subject	M1-M2-M3	Target students
1969 - 1973	Technology	5 - 3 - 3	Female and male students (compulsory subject)
1973 - 1981	Technology	3 - 3 - 3	Male students (Compulsory subject)
1981 - 1987	Life technology	3 - (4 - 6) -	Male students (Compulsory subject)
1987 - 1995	Technology, Technology-home-economics	3 - (4 - 6) -	Female and male students (Compulsory subject)
1995 - present	Technology-industry	1 - 2 - 2	Female and male students (Compulsory subject)

(Ex) 1-2-2: M1 (1st middle school) → 45 minutes/week
M2 (2nd middle school) → 90 minutes/week
M3 (3rd middle school) → 90 minutes/week

BEST COPY AVAILABLE

United States

Middle school technology education in the U. S. has a longer history than that of Korea. However, as can be seen in Table 2, technology education in the U. S. has also had many changes and revisions.

Table 2. Changes in technology education (Modified from Kim, 1994)

Time Period	Name of subject	Target students
1880 – 1920	Manual Training	High school
1880 – 1940	Manual Arts	Secondary school
1920 – 1990	Industrial Arts	Elementary school, Secondary school, Adult
1950 – present	Industrial Technology	Kindergarten, Elementary school, Secondary school, Adult
1970 – present	Technology education	Kindergarten, Elementary school, Secondary school, Adult

Middle School Technology Education Curriculum

Goal

In Korea, the goal of technology education is to provide experiences that help middle school students understand the basic concept of technology and industry and to explore career opportunities. In the U. S., on the other hand, "the goal of technology education is to provide active learning situations that help the early adolescent explore and develop a broader view of technology" (ITEA, 1996, p. 38).

Contents

In general, the middle school technology education curriculum includes *manufacturing, construction, communication, transportation,* and *biotechnology.* The middle school technology education curriculum in Korea, however, also includes agricultural education, commercial education, and marine technology (Ministry of Education [MOE], 1994).

Comparison of Technology Education

It is difficult to compare middle school technology education in two countries because of the different educational systems and backgrounds. Therefore, I would like to compare the general aspects of two individual schools: the attached middle school of the Korean National University of Education and Akira Toki Middle School in Wisconsin.

The attached middle school of the Korean National University of Education can be a representative of all middle schools in Korea. Table 3 shows the differences and similarities of the two schools.

Table 3. The comparison of middle school technology education in two schools (MOE, 1994; Nelson, 1997)

The attached middle school of the Korean National University of Education		**Akira Toki Middle School, Wisconsin**	
M1	Compulsory subject	6th	Compulsory subject
Contents	Humans and technology Basis of drawing Use of computer ⇒ communication	Contents	Broad comprehensive introduction to technology. Examples: robotics, graphics, video-audio technology, and basic programming ⇒ communication, construction, transportation, manufacturing
M2	Compulsory subject	7th	Compulsory subject
Contents	Use of material Use of machines Use of electricity Basis of house drawing ⇒ manufacturing, communication, construction, transportation	Contents	The areas of transportation and communication are emphasized. Example: universal model, CO2 dragster, Computer Aided Drafting(CAD), and Computer Numerical Control(CNC) ⇒ communication, transportation
M3	Compulsory subject	8th	Elective subject
Contents	Industry and life Occupation and career Agriculture technology Industry technology Commerce and management Flow and trade Ocean and marine technology ⇒ biotechnology	Contents	Fun with technology / video technology Engineering technology / designing, creating, and using technology systems Technology learning station revisited / music video technology ⇒ communication, construction, manufacturing

Conclusion

Middle school technology education is a general education program. "It is intended to teach students about the processes that apply to the design, problem solving, and use of technological products and systems. In addition, it is intended to assist students to develop the ability to assess the impact and consequences of technology" (ITEA, 1996, p. 38).

Technology education in the middle school is as fundamental as mathematics and science for all students regardless of career goal. That is, technology education in the middle school does not have to connect to actual future work and careers. Therefore, middle school technology education should be a core curriculum for all students in every country of the world.

References

International Technology Education Association. (1996). *Technology for all Americans : A rational and structure for the study of technology.* Reston, VA: Author.

Kim, J. (1994). *Technology Education.* Taejeon, Chungnam: Chungnam National University, Department of Technology Education.

Ministry of Education (MOE). (1994). *Technology and industry curriculum in the middle school* (written in Korean). Seoul, Korea: Author.

Nelson, D. (1997, January). Akira Toki Middle school home page. Available: http://www.madison.k12.wi.us/toki/teched.htm [Nov. 20, 1998].

Yi, S. (1997). Technology education in Korea: Curriculum and challenges. *The Journal of Technology Studies, 23*(2), 42-49.

Feuerstein's Instrumental Enrichment:
What Does It Have To Do with Mathematics Education?

Parisa Vafai
Integrated Teaching and Learning
The Ohio State University
Champion Middle School
vafai.2@osu.edu

Duane is a student in a pre-algebra class at an inner-city middle school who, despite his brilliant debates about the political and economical future of the African-American male "from the ghetto," as he puts it, in American society, has an IQ of 98. He is 16 years old, and whether he gets passing grades or not he will be going to high school next year because of his age. He lives with his mom, who is a single parent, and does not see his father, who is in and out of jail. He cannot read very well, and is totally clueless in the mathematics classroom. If we regard education as the means for transforming children's futures by giving them a chance to do better than their parents, thus far we have failed him.

The public education promise is to rescue children from the vicious circle of generational poverty and to help them up the spiral of success by giving them the knowledge and the know-how that at least provide them with a few more opportunities than their parents had. Unfortunately, this dream is often not realized in inner city schools. The children of the poor stay poor and the children of the rich get all the opportunities a public education has to offer. Even in research projects at the university level, we usually focus on children with an average IQ. The rest we label with fancy names and track them accordingly.

> .....IQ tests have permeated the entire educational and vocational system and become entrenched in it. Whatever reticence education may have had toward the adoption and application of psychological theories, its acceptance of the IQ test as a major assessment tool of deductibility and trainability, and general intelligence level has been almost total. (Feuerstein, 1980, p. 6)

The basic premise of an IQ test is to measure what a child already knows (IQ = (mental age/ chronological age) x 100) without any regard for her/his cultural or environmental background. To assign a number to an individual's intelligence implies we are measuring a fixed, unchangeable entity. The current educational process views intelligence as a fixed measure of ability across the entire life span of an individual, and represents a passive-acceptance approach. This approach does not allow for an explanation for the underlying processes responsible for an individual's performance or about the individual's capacity to improve it.

Maria Montessori, Jean Piaget, and L. S. Vygotsky did view intelligence as a changeable entity. Montessori found, as many others have found since, that the children who are at risk for learning or have disabilities have a combination of deficits in attention, order and organization, and gross and fine motor skills. She concluded that if learning of these skills were inherit in the methods of education, and if the child repeated these skills every day in every activity, it would help him/her to get over these deficits. Pickering asserts, "The procedures introduced to the child through these presentations (Montessori) and the structure of the classroom are seen to enhance attention, increase self-discipline and self-direction, order, organization and a work-cycle. High risk children are seen to benefit from the structure, the procedures and the curriculum" (1978, p. 4). In essence, Montessori did not look at the child's intelligence as a fixed entity, and believed that with the right environment and appropriate tools, a child can overcome her/his deficiencies. This belief resonates in Vygotsky's Zone of Proximal Development (ZPD) theory. The ZPD is defined as, "the distance between the actual developmental level as determined through independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978). Piaget however, was more of a radical constructivist, and did not emphasize the teacher's role as important in a child's construction of knowledge.

Rueven Feuerstein, a student of Piaget, differs from his mentor in a major way. He believes the role of a teacher is crucial in the child's cognitive development. He also differs from Montessori and Vygotsky in a major way; and that is the argument of sensitive period. Montessori believed that each child during a specific period is directed by an overpowering force and interest to center his/her attention on specific aspect of the environment, to the exclusion of all else. This is a passion that drives the child from the unconscious and leads him/her to conscious and creative activities. These sensitive periods occur from birth through the age of six. She believed that if the child does not have the appropriate environment, or the appropriate direction during the opening of each period, she/he would miss the skills and knowledge gained through the period and those abilities would stay retarded. Vygotsky also believed, "for each subject of instruction, there is a period when its influence is most fruitful because the child is most receptive to it" (1986, p. 186). Feuerstein's theory is built on the assumption that the intervention can happen at any point of an individual's life span. Most documented cases in his books are on K-12 children.

To revolutionize the educational process, we need to view the human as an open and modifiable organism who can be taught and who can learn what his environment offers him at any age, as these pioneers did. A different method of assessment is needed to evaluate the individual's capacity to learn and hence to be modified.

Feuerstein's Learning Potential Assessment Device (LPAD) promises to achieve the assessment goal. The LPAD is not, in any conventional sense, a test. Rather, it is an assessment of cognitive modifiability of the individual. In this assessment device, the assessor is required to "reassure, encourage and teach the child how to do the test. In other words it was a way of offering the child very intense mediation" (Feuerstein, 1980). The LPAD investigates children in several areas: (a) the ability to grasp the principle underlying a problem; (b) the amount and nature of teaching investment required for the child to acquire the principle; (c) how well that principle is transferred to different tasks of varying complexity; (d) and whether a child responds differently to problems expressed in different modalities, such as language, figures, numbers, and pictures, and how different training strategies affect the child's performance.

Using the results of this assessment device, the teacher is then able through mediated learning to help a child overcome her/his deficiencies. Feuerstein came up with a program of mediated learning, Feuerstein's Instrumental Enrichment (FIE) program, with the purpose of modifying the cognitive structure of the individual and thus producing and setting in motion his/her further development. The program consists of 15 instruments made up of paper and pencil exercises, providing materials for one hour lessons three to five times a week for two to three years. Each instrument focuses on a specific cognitive deficiency and provides experience in overcoming it. The instruments are selected for each individual to fit deficiencies identified in the LPAD results.

This poster presentation describes three FIE instruments and discusses a theory of integrating them into the mathematics curriculum.

References

Feuerstein, R. (1980). *Instrumental enrichment: An intervention program for cognitive modifiability*. University Park Press.

Montessori, M. (1967). *The absorbent mind*. New York: Dell.

Pickering, J. S. (1978). Successful applications of Montessori methods with children at risk for learning disabilities. [ERIC Document Reproduction Service No. ED 343 659]

Vygotsky, L. S. (1986). Thought and language. Translation newly revised by A. Kozulin. Cambridge, MA: MIT.

Vygotsky, L. S. (1987). *The collected works of L .S. Vygotsky*. Rieber & Carton, Eds. New York: Plenum Press.

Author Index

SE063165

ERIC®

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

REPRODUCTION RELEASE

(Specific Document)

I. DOCUMENT IDENTIFICATION:

Title: Proceedings of the Third Annual Spring Conference of the Mathematics, Science, and Technology Educators & Researchers of The Ohio State Univ.

Author(s): Kelly M Costner   Michelle K Reed   editors

Corporate Source:

Publication Date: Dec 1999

II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, *Resources in Education* (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic media, and sold through the ERIC Document Reproduction Service (EDRS). Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.

If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following three options and sign at the bottom of the page.

The sample sticker shown below will be affixed to all Level 1 documents	The sample sticker shown below will be affixed to all Level 2A documents	The sample sticker shown below will be affixed to all Level 2B documents
PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY ____ Sample ____ TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE, AND IN ELECTRONIC MEDIA FOR ERIC COLLECTION SUBSCRIBERS ONLY, HAS BEEN GRANTED BY ____ Sample ____ TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY ____ Sample ____ TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
1	2A	2B
Level 1	Level 2A	Level 2B
[✓]	[ ]	[ ]
Check here for Level 1 release, permitting reproduction and dissemination in microfiche or other ERIC archival media (e.g., electronic) *and* paper copy.	Check here for Level 2A release, permitting reproduction and dissemination in microfiche and in electronic media for ERIC archival collection subscribers only	Check here for Level 2B release, permitting reproduction and dissemination in microfiche only

Documents will be processed as indicated provided reproduction quality permits.
If permission to reproduce is granted, but no box is checked, documents will be processed at Level 1.

I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche or electronic media by persons other than ERIC employees and ~~its~~ system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries.

Sign here, → please

Signature: Michelle K Reed	Printed Name/Position/Title: Michelle K Reed co-editor	
Organization/Address:	Telephone:	FAX:
	E-Mail Address: reed.253@osu.edu	Date: 2/18/00

(over)

III. DOCUMENT AVAILABILITY INFORMATION (FROM NON-ERIC SOURCE):

If permission to reproduce is not granted to ERIC, *or*, if you wish ERIC to cite the availability of the document from another source, please provide the following information regarding the availability of the document. (ERIC will not announce a document unless it is publicly available, and a dependable source can be specified. Contributors should also be aware that ERIC selection criteria are significantly more stringent for documents that cannot be made available through EDRS.)

Publisher/Distributor:
Address:
Price:

IV. REFERRAL OF ERIC TO COPYRIGHT/REPRODUCTION RIGHTS HOLDER:

If the right to grant this reproduction release is held by someone other than the addressee, please provide the appropriate name and address:

Name:
Address:

V. WHERE TO SEND THIS FORM:

Send this form to the following ERIC Clearinghouse:

ERIC/CSMEE
1929 Kenny Road
Columbus, OH 43210-1080

However, if solicited by the ERIC Facility, or if making an unsolicited contribution to ERIC, return this form (and the document being contributed) to:

ERIC Processing and Reference Facility
1100 West Street, 2nd Floor
Laurel, Maryland 20707-3598

Telephone: 301-497-4080
Toll Free: 800-799-3742
FAX: 301-953-0263
e-mail: ericfac@inet.ed.gov
WWW: http://ericfac.piccard.csc.com

-088 (Rev. 9/97)
PREVIOUS VERSIONS OF THIS FORM ARE OBSOLETE.