

# The Journal of Mathematics and Science:

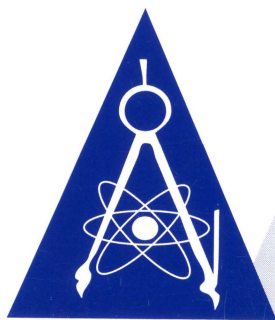
COLLABORATIVE EXPLORATIONS

Volume 2, Number 2 Fall 1999

## SPECIAL ISSUE

### Charlottesville Conference, March 1999

Preparing Virginia's K-8 Teachers in Math and Science



Virginia Mathematics and Science Coalition

# The Journal of Mathematics and Science:

COLLABORATIVE EXPLORATIONS

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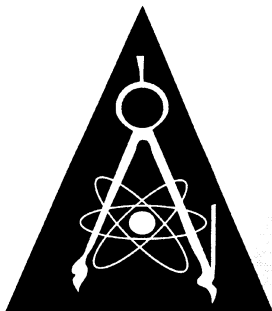
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## **SPECIAL ISSUE**

**Charlottesville Conference**

**Coordinating Editor  
for this Special Issue**

Stephen T. Thornton  
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## Editor's Note

This special issue of *The Journal of Mathematics and Science: Collaborative Explorations* is devoted to the proceedings of a Virginia statewide conference hosted by the University of Virginia in Charlottesville on March 5-6, 1999. The Conference was conducted by the Virginia Mathematics and Science Coalition and the National Science Foundation-supported Virginia Collaborative for Excellence in the Preparation of Teachers, with additional support provided by: the University of Virginia's Provost, Schools of Education, Engineering, and Arts and Sciences, and Center for Science, Mathematics, and Engineering Education; the Virginia Department of Education; and the Appalachian Educational Laboratory.

The conference was entitled *Preparing Virginia's K-8 Teachers in Math and Science* and was directed by Stephen Thornton, Professor of Physics, University of Virginia, who also serves as coordinating editor of this special issue. Other members of the Organizing Committee include Jerry Benson, Mike Bentley, Bob Boggess, Thelma Dalmás, Daria Giffen, Bill Haver, Julius Sigler, Donna Sterling, Curt Wall, and Grant Woodwell.

The Conference was conducted in response to major increases in the mathematics and science portion of the licensure requirements for prospective elementary and middle school teachers that have been adopted by the Virginia Board of Education. The new licensure requirements will become effective for institutions of higher education on July 1, 2000.

The current requirements for prospective elementary school teachers specify only that future teachers complete a bachelors degree in an Arts and Science discipline. Under these requirements, a number of Virginia colleges and universities have approved teacher preparation programs requiring as few as a total of six credit hours (or less) in mathematics and science. The new expectations are much greater. Patty Pitts, Director of Teacher Education and Licensure of the Virginia Department of Education, opened the conference by summarizing the new requirements for the attendees. In the abstract to her talk she stated that under the new requirements to take effect on July 1, 2000:

“Individuals seeking licensure through the alternative route to licensure in

Early/Primary Education PreK-3 must complete 9 semester hours in mathematics and 9 semester hours in science. The Elementary PreK-6 endorsement via the alternative route requires individuals to complete 12 semester hours in mathematics and 12 semester hours in science. The licensure regulations, which are aligned with the Virginia Standards of Learning, set forth the specific competencies in mathematics and science that must be incorporated in approved programs preparing teachers to teach in early/primary and elementary education.”

The current requirements for the middle school endorsement are even weaker. Under the current requirements, teachers may obtain a middle school endorsement by completing the equivalent of a minor in two of the following disciplines: mathematics, science, English, and social science. Then based upon this certification, *they are fully certified to teach any area*. Hence, many individuals are currently teaching mathematics and/or science full time in middle schools based upon their academic minors in English and social science. The new requirements remove this option. As Ms. Pitts stated, under the new requirements:

“Individuals seeking licensure in Middle Education 6-8 must complete at least two areas of concentration in the core areas of mathematics, science, English, and social science. *The areas of concentration will be noted on the license, and teachers will be restricted to teaching in their areas of concentration* (emphasis added). The alternative route requires 21 semester hours in each area of concentration, and institutions of higher education preparing teachers to teach middle education must incorporate in their approved programs the competencies set forth in the licensure regulations. Content in mathematics must include algebra, geometry, probability and statistics, and applications of mathematics. Science preparation must include biology, chemistry, physics, and earth and space science.”

The Conference was attended by teams of science, mathematics, and education faculty from almost every college and university in Virginia that offers teacher preparation programs, and faculty from 15 community colleges (225 participants in all). Virginia’s colleges and universities face a major challenge in meeting the new licensure requirements for future elementary teachers and preparing sufficient numbers of middle school mathematics and science teachers who satisfy the new requirements. However, as reported at the conference and in the following proceedings, much has already been accomplished.



## **CHALLENGES FOR SCIENCE AND MATHEMATICS FACULTY**

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The increased science and mathematics teacher licensure requirements for K-8 teachers are clearly necessary to prepare teachers to appropriately teach the new Virginia SOLs [1]. The expectations of a program equivalent to 12 hours of science and 12 hours of mathematics for the PreK-6 endorsement and the 21 hours each of math and science to teach middle school math and science must be chosen very carefully indeed if future teachers are to be prepared to teach the specific SOL content, as well as "practical applications and the use of appropriate technology". Most Virginia colleges and universities are not currently offering the appropriate courses nor the courses taught in the appropriate manner to meet new licensure requirements. Both interdisciplinary courses and interdisciplinary degree programs may be required.

It is clear from Patty Pitts' remarks on teacher licensure [2] that math and science faculty have our work cut out for us. One message I would like to give you is that what's best for a small community college is not necessarily what is best for an urban university, and what is best for an urban university is not necessarily what's best for a small private college, and so forth. Every one of our colleges and its resources is different. However, physical science is physical science, and we physicists basically teach the same material--we just do it different ways. All of us much teach the competencies as described in the teacher licensure requirements, and our graduating students must go forth and teach the math and science standards as espoused both at the state and national levels.

Ertle Thompson, the senior professor of science education at the University of Virginia (UVa), has probably produced more graduates of science education than anyone else in the state. He tells me that 25 years ago the math and science content courses for preservice teachers taught at the University of Virginia were better than they are today. Professor Thompson says that senior professors, chairpersons, and even Deans taught education students. What has happened? I can only speculate, but at UVa the 5-year BA/MA program for education students started about 20 years ago. There are no longer undergraduate education students, nor undergraduate education degrees. Those students became assimilated into our College of Arts & Sciences and now have the same math and science requirements

as all college students. After the 5-year program was instituted, there was no need for special math and science courses for education students, so the special courses were dropped. If prospective teachers are not math and science majors, they take the same math and science courses as all other non-technical majors. These courses are usually the lowest level, easiest courses offered in math and science; they almost never have labs.

In my own department we have a separate introductory physics course for our prospective majors. We also have separate introductory courses for engineering majors, other science majors, pre-med students, and even architectural students, not to mention those special courses to teach the masses. We do a great job teaching the non-science students, but those courses are not appropriate for preservice teachers. In my opinion, preservice teachers should be one of the most important service clientele we teach. But until this past semester, we did not have a dedicated, hands-on, inquiry based course in physical science taught in a cooperative learning environment using technology such as graphing calculators and probes.

Now let's look at the challenges faced by math and science departments. First, for preK-6 we need to look at the Virginia Standards of Learning (SOLs) that every teacher must know. Let's look at a couple of SOLs.

In grade 5, we find

5.6 The student will investigate and understand characteristics of the ocean environment. Key concepts include

- geological characteristics (continental shelf, slope, rise);
- physical characteristics (depth, salinity, major currents);
- biological characteristics (ecosystems); and
- public policy decisions related to the ocean environment (assessment of marine organism populations, pollution prevention).

In grade 4, we find

4.4 The student will investigate and understand basic plant anatomy and life processes. Key concepts include

- the structure of typical plants (leaves, stems, roots, and flowers);
- processes and structures involved with reproduction (pollination, stamen, pistil, sepal,

- embryo, spore, and seed);
- photosynthesis (chlorophyll, carbon dioxide); and
  - dormancy.

The reason I list these two standards is that as a physicist, I would be reluctant to even agree to teach an interdisciplinary class that included these subjects as our objectives. I would need specialists in both ocean systems and life science to teach this material. Similarly, I could list a physical science standard that these specialists would have difficulty teaching. Yet, we require our K-6 teachers to master this material! It is not trivial, and research and experience shows the answer is not to have students read the material in a textbook and fill out worksheets. I look at these SOLs, and I see experiments to do on sedimentation, salinity, photosynthesis, and a field trip into the local schoolyard, woods, and fields.

The same thing is true in math. Let's look at a math SOL.

- 5.17 The student will collect, organize, and display a set of numerical data in a variety of forms, given a problem situation, using bar graphs, stem-and-leaf plots, and line graphs.

I took a lot of math in high school and college, but I don't know what a stem-and-leaf plot is. Most of us know that college students have considerable difficulty making graphs and plots. How are we going to teach all the math material in just 12 credit hours? I am not sure, but I know we can't do it in fewer credit hours. At UVa we are developing three new math courses, three new science courses, and two capstone courses for our K-8 preservice education students:

Three new basic math courses:

- geometry and measurement
- numbers and number measurements
- data and chance

Three new basic science courses:

- physical science
- life science
- earth/space science

Two new interdisciplinary capstone courses:

- one semester course in which students perform mini-projects in collaborative working groups. Possible projects include forensics, sound, global positioning satellites, modeling, and material science.
- one semester course in which students do a research project in a collaborative working group under the direction of a faculty mentor in arts & sciences, education, engineering, medicine, or nursing.

Four of these new courses have already been taught and others are under development. The capstone courses will be interdisciplinary in nature, and will be team-taught. We still need to work out the details of course credit, faculty teaching loads, and course mnemonics. Our eight courses should prepare the pre-service teacher to be able to do research with their school children, empower the new teachers to be lifelong learners, and prepare the new teacher to be a Teacher of Science.

We are not sure this will work. Every now and then we think we might need to have 4 credit hour courses, instead of 3 credit hours. We will try it and see how it works. Again I emphasize what works at UVa may not work anywhere else. But there will be similarities among all the math and science courses. One of the things we hope to accomplish at this conference is for all of us to learn about courses in our discipline at other colleges. In this regard, the community colleges and major research universities are on the same footing, because we are talking about introductory courses for freshmen and sophomores. It is well documented (see, for example, [3]) that community colleges teach general courses to a significant fraction of preservice teachers.

We have two National Science Foundation grants at UVa to help us develop the courses and institute them. We have a lot remaining to do, including convincing the university and our colleagues that this is what we should be doing. I should mention that these courses are separate from the methods and technology courses that preservice teachers must also take. Other than perhaps using probes with graphing calculators, we do not teach technology in the content courses, although we do use it. Students must be exposed to technology in all these courses. In my physical science course, we use Excel to analyze and plot data routinely. The students like it. We use probes with both graphing calculators and computer based systems to take and record data.



Before leaving the preK-6 preservice situation and turning to middle school, I want to mention how important it is for math and science faculty to work closely with our education colleagues. We are blessed at UVa to have a close working relationship. The elementary education group gives us a standing invitation to attend their meetings, and the math and science education faculty is invited to our meetings. The education faculty have their own challenges, not the least of which is how they are going to fit the new increased teacher licensure requirements into their curriculum.

I discuss the middle school situation with some trepidation. It is well documented [4] that a high percentage of middle school teachers teach outside their field of study. We do not have a separate grade 6-8 teacher preparation program at UVa, and our education faculty does not know if they will. It looks tough.

Remember that the middle school teacher licensure requirements require endorsements in two of the following four areas: math, science, language arts, social studies. The requirements require the equivalent of 21 hours in each endorsement in addition to required courses in the other two concentrations. It appears to many of us that there are simply too many course requirements to receive a degree. Let me briefly look at one possibility for a teacher who wants to be endorsed in math and science in middle school. The student must have 21 hours of math and 21 hours of science. In addition the student must also have 12 hours of English, 15 hours in history and social science, their education courses, and about 36 hours in their major courses. How can this be done? It probably cannot, unless the student majors in math or science.

But a student who majors in math or science will probably be endorsed to teach secondary school as well, and experience has shown that most of those students will opt to teach in secondary, not middle, school. A significant number of students majoring in math and science and initially planning on being teachers are deciding to enter other careers that pay more money and are less stressful!

We believe the answer to middle school teacher preparation will lie in interdisciplinary degree programs, and that is a major part of this conference. However, at UVa all our interdisciplinary programs are honors programs, and a GPA of 3.4 is required. We believe

we have a major effort ahead of us to institute an interdisciplinary degree program at UVa. The interdisciplinary degree will not be limited to math and science, because language arts and social studies students have the same difficulty. We submitted a teaching initiative proposal last year to the university to study this problem, and this conference is our culminating event. In the next months we will begin serious discussions about an interdisciplinary degree, and we are very interested in what we hear at this conference.

I have a concern that the Arts & Sciences professors are going to think that we are trying to institute an easy degree for education students. Of course, that is very far from the truth. We believe that such a degree will be popular with pre-law, journalism, and pre-MBA students, for example.

I would now like to make some personal observations about what I think must happen for us to produce better-prepared math and science teachers and for our K-8 students to be better prepared.

- 1) My experience is that many math and science professors are not even aware of the problem here at UVa. Those with children in school sometimes worry about it, but don't have time to really get involved.
- 2) We have to convince our colleagues that teaching preservice teachers should be one of our very highest priorities.
- 3) Excellent teaching for those concentrating on educating preservice teachers must become a suitable criterion for tenure promotion. Research and outreach in math and science education must be considered along with teaching and service. We must convince our colleagues, chairs, and deans of these criteria. And as Jerry Benson, Dean of Education at JMU, reminded us at our conference steering committee meeting, we must convince our Vice Presidents, Provosts, and Presidents as well.
- 4) I don't think we can compromise on the 12 hours each of math and science for preK-6 preservice teachers. I realize the requirements now have an exception that states the equivalent of these courses is acceptable, but I don't see how that will be possible. We think we need more than 12 credit hours, not less. On the other hand, I understand the difficulty education schools have in getting all the required courses in the curriculum.
- 5) The Virginia Department of Education will have to recertify all 37 teacher preparation programs in Virginia. All of us need to offer to help with this effort. I served on a

committee last year to help set up criteria for program approval. It was interesting. As a result of that effort, I think I will be able to help the Curry School of Education with their program approval. And I look forward to helping with site visits at other colleges. I hope you become involved, because it is an important responsibility.

- 6) I would like to see more math and science education professors in Virginia. Most of you have other responsibilities besides math and science. There are probably less than ten professors of each discipline that only do math or science education. I would like to see more math and science professors in Arts & Sciences concentrate on this effort. There are even fewer of us, and there are more in math than in science.
- 7) The teaching profession needs to rise in stature. Salaries must increase dramatically to make teaching competitive with business.
- 8) Teaching can be very satisfying, but the workplace must improve.
- 9) We will hear later from Julius Sigler about the demographics of the teaching profession. We have a tremendous crisis, and a week does not pass when we don't hear of it on TV or read about it in the papers.

A recent report issued by the U.S. Department of Education called *A Back to School Report on the Baby Boom Echo: America's Schools are Overcrowded and Wearing Out* [5] indicates that we will need 2.2 million teachers in the next 10 years, and that during the next 10 years, over 60% of the nation's K-12 teachers will retire or quit. Where are all these new teachers coming from? Our education schools need to grow, and we must do a better job of educating the teachers.

I am guardedly optimistic about our chances. During the past few weeks my optimism has grown as I have heard from so many of you. We think it is absolutely amazing that so many of our colleagues throughout Virginia have come to this conference with a common challenge--to improve the education of our future K-8 teachers. I expect to gain several insights, especially about interdisciplinary degrees, because that is becoming an issue we must face here at UVa. I know mostly about physical science courses, and if I could help you, I would be glad to share my experiences. I hope we can share with each other our successes and failures. Our children's future depends on it. ■

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## EDUCATION SCHOOL CHALLENGES: THE INCREASING DEMANDS ON K-8 TEACHERS

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The educational needs of future K-8 teachers in the areas of mathematics and science are greater as a result of the increased (and, I would add, appropriate) student expectations in the area of mathematics and science as enunciated in the SOL and the specific content areas as described in the new licensure requirements. The sophistication and understanding of science and mathematics that is needed at both the elementary school and middle school levels is indeed substantial.

However, proficiency in science and mathematics is only one portion of the total needs of new teachers. How are we all, from the Colleges of Arts and Sciences and the Colleges of Education, going to best provide the educational needs within the very restrictive total time that we have available.

“It takes a University to educate a teacher.” This is a paraphrase Secretary of Education Richard Riley used recently in addressing the American Association of Colleges of Teacher Education. The preparation of future teachers is a university wide responsibility. Approximately 66% to 80% of the total college preparation for a future teacher occurs outside the colleges/schools/departments of education. My colleagues in arts and sciences have a greater opportunity to impact these future teachers than my colleagues in education. And of the time focused in education courses, approximately 50% of that time is allocated to field based experiences (including student teaching or internships).

It can also be said that it could (or should) take a lifetime to educate a teacher. The ideal elementary teacher, covering all the basic disciplines plus art, music, etc., would certainly be the epitome of the Renaissance Man (or in this case, more likely woman). In addition to being well versed in the four promoted disciplines of the Standards of Learning, i.e. History/Social Studies, English/Language Arts, Mathematics and the Natural Sciences, the competent elementary teacher must be a master of language development, reading, technology, appreciation of the fine arts, developmental/cognitive psychology, health and wellness, parental relations, governmental relations, and much more.

So although the task sounds daunting, where does that leave those of us who believe that preparing for the education of future generations is the noblest activity in which one can be engaged? We can start with the body of accumulated knowledge regarding the practice of teaching and the preparation of teachers.

For the purposes of our discussion today, I would offer the following findings for your consideration. These findings have been replicated in repeated reports referenced at the end of this article [1, 2, 3, 4, 5, 6, 7].

- When we think of teaching, we need to think of the teaching – learning interaction. Teaching is made up of knowledge, skills and dispositions informed by the content area, human development and cognition, and instructional strategies. The mandate to the elementary and middle school teacher is to teach **all** students. Therefore, they must have content pedagogical knowledge that allows them to represent ideas in such ways that other people, of varying abilities and learning styles, may access them.
- What teachers know and can do is the most important influence on what students learn. Yes, better preparation in content areas, as well as pedagogical studies, does make a difference.
- However, simply majoring or minoring in a content area does not guarantee that teachers will have the kind of subject matter knowledge they need for teaching. What is needed is knowledge of subject matter that enables it to be a base for **understanding** core concepts and modes of inquiry in the discipline – a sense of structure of the discipline and its connection to other disciplines.
- Pedagogical knowledge needs to be tied to content.
- When put in stressful situations, teachers tend to teach as they were taught. (Remember the 66%/80% - 34%/20% split earlier – who are the role models?)
- We are limited in the amount of time we have to prepare the **entering** professional. Our public and the State Council of Higher Education keep pushing for a reduction in credit hours, greater efficiencies. Also, the entering salary of the profession places a real limit on the payout for investment.

So where do we go from here? Again, I would offer the following points for your consideration.

- We all have the same goal: to place the most highly qualified entering professionals in the

K-12 classrooms of our nation. We are truly partners in this effort.

- Remember the elementary teacher (in most instances) covers all four of the primary SOL noted content areas. Therefore in teacher preparation, we have to give appropriate instructional attention to all four, plus pedagogical studies. More coursework in math and science may be better (or preferred), but it is not always possible – doing it differently is a very real goal.
- Future elementary and middle school teachers need a thorough understanding of the content they will need to teach – not a lot more new content. For example, in mathematics, we need to ensure understanding of the concepts and not introduce more algorithms to memorize.
- In your own classes, think of yourself as one of the most powerful pedagogical models for future teachers – model effective instructional strategies.
- Appropriately integrate the use of technology in your classes and instruction.
- We in education need to reach out and effectively involve our arts and sciences colleagues in “teacher education” courses, e.g., co-supervising of student teachers, integrating education methods courses with content courses, etc.

At that same conference I mentioned earlier, Dr. Stanley Ikenberry, president of the American Council on Education, announced that he was working with presidents of institutions to develop and implement an “University audit” for teacher education: an audit where all facets involved in the education of future teachers would be held accountable for the quality of **their** product. What we are about today and tomorrow is to start down the path of building an infrastructure in Virginia for preparing quality teachers – not a demo project here or there, but a system that really enables people to teach in much more informed and powerful ways. This will take the whole university working together. It is **our** future. ■

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## **VIRGINIA COMMONWEALTH UNIVERSITY'S PROGRAM FOR K-6 AND 6-8 TEACHERS: THE INTERDISCIPLINARY B.S. IN SCIENCE**

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Virginia Commonwealth University (VCU) has very recently revised its requirements for the K-6 Certification to include a total of 21 hours in mathematics and science as well as a three credit hour methods course in mathematics and science. This requirement includes a physical science and a biological science course, each with a laboratory component, a contemporary mathematics course with extensive student projects, collaborative work and applications, a statistics course and interdisciplinary science and mathematics course. We believe that as students complete these requirements they will meet the new State K-6 licensure requirements in all areas, with the exception of geometry. We are developing a new geometry course that we hope will be required of all future teachers.

The challenge of preparing middle school teachers to teach mathematics and/or science is much more difficult. VCU has been preparing very few middle school teachers of mathematics and science. We typically averaged less than one middle school science teacher and less than one middle school mathematics teacher per year. This paper provides a description of our interdisciplinary degree in mathematics and science that appears to be attracting significant numbers of students with an interest in teaching mathematics and/or science at the middle school level.

For the past several years, mathematics and science faculty at Virginia Commonwealth University (VCU) have worked along with teacher education faculty to align the mathematics and science requirements in the teacher preparation program with the expected increases in teacher licensure requirements. We do not believe that the resulting hours now required for our students preparing to teach in grades K-6 are disjoint from the competencies which have been established by the Virginia Board of Education. The new requirements emerged from an agreement between the disciplinary faculty and the teacher education faculty that while increased preparation standards needed to be established for the future teachers who are being trained in our program, the courses developed and pedagogy employed to achieve these standards could not be just "more of the same" course work typically delivered in lecture format. From this understanding, VCU has very recently revised its requirements for the K-6 certification to include a total of 21 semester hours in mathematics and science and a three-credit hour course in each of mathematics and science. This requirement includes a physical

science course and a biological science course, each with a laboratory component. Also required are a statistics course and a contemporary mathematics course with extensive student projects, collaborative work, and applications. An interdisciplinary science and mathematics course rounds out the 21 credits.

Nearly all of the course options available to students in this program were developed under a grant to VCEPT, the Virginia Collaborative for Excellence in the Preparation of Teachers, though the Division of Undergraduate Education at the National Science Foundation. All of these courses feature participatory, hands-on, discovery oriented learning. For example, the CBL explorations in the precalculus course require that physical phenomena graphed by the CBL from experimental data collected be modeled by mathematical equations determined by the student [1]. Students discover the exponential functions which model according to Newton's Law the heat gain or loss of a probe; they find the parabolic functions which model the distance from an origin point of a ball when rolled up a ramp; and they develop the sine or cosine function which models the distance of a swinging ball (pendulum) from its point at rest. These courses were developed or refined by teams of college faculty and practicing teachers and were pilot tested in team teaching efforts involving faculty from several VCEPT institutions. Joining Virginia Commonwealth University, lead VCEPT institution, are partner institutions: Longwood College, Mary Washington College, Norfolk State University, College of William and Mary, Virginia Union University, University of Virginia, the Mathematics and Science Center, along with J. Sargeant Reynolds, Germanna, and Tidewater Community Colleges.

One student option for an interdisciplinary science and mathematics course is the "Experiencing Science" course developed in conjunction with the Science Museum of Virginia [2]. This course is taught by a team of faculty from the Science Museum of Virginia, J. Sargeant Reynolds Community College, and Virginia Commonwealth University and is offered at the Science Museum taking advantage of the exhibits and experimental apparatus featured at that location.

Under the leadership of Dr. Loren Pitt at the University of Virginia, with VCEPT support, we are developing a new applied geometry course which we hope will be required of all future teachers [3]. We believe that as students complete these requirements they will meet the new

Virginia K-6 licensure requirements and all mathematics and science competency areas. The Elementary Education Mathematics and Science preparation requirements are recapped as follows:

**ELEMENTARY EDUCATION**  
**Preparation to Teach Mathematics and Sciences**

*Requirements*

Mathematics and Statistical Reasoning	6 credits
Natural Sciences	12 credits
Interdisciplinary Mathematics and Science	3 credits
Teaching Mathematics and Sciences	6 credits
Recommended Additional Geometry Course	3 credits

The challenge of preparing middle school teachers to teach mathematics and/or science is much more difficult. Virginia Commonwealth University has been preparing very few middle school teachers of mathematics and science. We typically averaged less than one middle school science teacher and one middle school mathematics teacher per year. We have recently developed an interdisciplinary degree in mathematics and science that is beginning to attract significant numbers of students with an interest in teaching mathematics and/or science at the middle school level. The focus of the B.S. in Science Degree program is interdisciplinary breadth in mathematics and science training without targeting theoretical senior level/graduate level discipline courses which are structured as preparation for M.S. degree programs in the discipline. The program features strong course work extending through a calculus course, a modeling course, and a linear algebra course in mathematics and courses such as Oceanography, Meteorology and Climatology, and Ecology in Science. In the Linear Algebra course, students learn the theory of matrices and the application of matrices to solving systems of linear equations. Although not required at the most advanced levels, mastery of these skills is required in the Virginia Algebra II Standards of Learning [4]. We believe that the B.S. in Science program is particularly appropriate for future middle school teachers of mathematics and science and can also be attractive for elementary teachers who would be prepared to assume math and science leadership roles such as lead teacher positions. Currently, VCU has about ten Mathematics Track and six Science Track majors

in the B.S. in Science Program. Some National Science Foundation scholarships and other scholarships offered through the Dean of Humanities and Sciences and the Dean of Education, support the program the outline of which is given below.

**Virginia Commonwealth University**  
**B.S. in Science Program**

<b>Core Courses for Mathematics or General Science Tracks</b>	<b>Credits</b>
<b>BIO 101</b> (Life Science), <b>OR</b> <b>BIO 102</b> (Science of Heredity), <b>OR</b> <b>BIO 103</b> (Environmental Science), <b>OR</b> <b>BIO 151</b> (Intro to Biological Science),with labs	4-5
<b>CHEM 101</b> (General Chemistry), <b>OR</b> <b>CHEM 110</b> (Chemistry and Society), with labs	4-5
<b>PHY 101, L101</b> (Foundations of Physics), <b>OR</b> <b>PHY 107</b> (Wonders of Technology), <b>OR</b> <b>PHY 201</b> (General Physics), with lab <b>OR</b> <b>PHY 207</b> (University Physics), with lab	4-5
<b>GEO 203</b> (Physical Geography), <b>OR</b> <b>GEO 204</b> (Physical Geography), with labs	4
<b>SCI 300</b> (Experiencing Science, Science Museum of Virginia)	3
<b>SCI 301</b> (Interdisciplinary Math and Science)	3
<b>MATH 151</b> (Pre-calculus)	4
<b>MATH 200</b> (Calculus I)	4
<b>STAT 208</b> (Statistical Thinking), <b>OR</b> <b>STAT 210</b> (Basic Practice of Statistics)	3
	33-37

General Sciences Track	Credits
<b>BIO 315/ENS 314</b> (Man and Environment), <b>OR</b> <b>BIO 332/ENS 330</b> (Environmental Pollution), <b>OR</b> <b>BIO 317</b> (Ecology)	3
<b>ENS/GEO 401</b> (Meteorology and Climatology)	3
<b>ENS/GEO 411</b> (Oceanography)	3
<b>PHY 103 and L103</b> (Astronomy)	4
<b>PHY 105 and L105</b> (Physical Geology)	4
Second sequence of Introductory Biology, Physics, and Chemistry courses with laboratories	12-15
Two additional courses at the 200 level or higher in mathematics, science, teaching mathematics and/or science with advisor's approval	6
	35-38
Mathematics Track	Credits
<b>CSC 128</b> (Computer Concepts and Applications), <b>OR</b> <b>CSC 255</b> (Structured Programming), <b>OR</b> <b>CSC 554</b> (Applications of Computers in Teaching Mathematics)	3
<b>MAT 131</b> (Contemporary Mathematics)	3
<b>MAT 211</b> (Mathematical Structures)	3
<b>MAT 303</b> (Geometry)	3
<b>MAT 310</b> (Linear Algebra)	3
<b>MAT 327</b> (Mathematical Modeling)	3
<b>MAT 351</b> (Applied Abstract Algebra)	3
Two additional courses at the 200 level or higher in mathematics, science, teaching mathematics and/or sciences with advisor's approval	6
	30

A cursory look at the above listed credit requirements for the B.S. in Science Degree might give the impression that the program requires many more credit hours than traditional degrees in mathematics, biology, etc. However, a more careful analysis reveals that the total credit requirements are comparable. For example, the B.S. in Mathematical Sciences includes 41 credits hours in the major plus 16 additional credit hours in physical and life sciences. Considering that 6 credits of the 63-67 credits in the B.S. in Science, Mathematics Track, are normally taken in Education methods courses, the 57 credits for the B.S. in Mathematical Sciences matches the lower end spectrum for credits required in the B.S. in Science, Mathematics Track. The comparison between the B.S. in Science, General Sciences Track, and the B.S. in Biology is similar considering that the latter requires 40 credits in the major plus 13 additional credits in mathematics and statistics along with 8 additional credits in physics.

We are optimistic that the B.S. in Science Degree will prove to be an attractive option for students preparing to teach mathematics and/or science at the middle school level. The program has also begun to enroll some students who are preparing to teach in the elementary grades. ■

## References

- [1] R. Farley and K. Wallo, "Student Discovery and Learning through Precalculus CBL Projects, *The Journal of Mathematics and Science: Collaborative Explorations* 2(1) (1999) 29-35.
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## **LIBERAL STUDIES AT LONGWOOD COLLEGE: PREPARING TEACHERS FOR VIRGINIA'S FUTURE**

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The Liberal Studies Major provides future teachers studying at Longwood College with an excellent opportunity to prepare for all aspects of teaching in elementary school classrooms. In the area of mathematics and science, the Liberal Studies Major contains a total of 24 hours of mathematics and science, and prepares future K-6 classroom teachers to teach all components of the Virginia Standards of Learning (SOL) in these disciplines. Longwood College is currently studying how requirements can be modified within the Liberal Studies Program to make it possible for students to complete the discipline specific course work that will be necessary for middle school endorsement.

### **Knowledge and Longing for Knowledge: Conceptions of Teaching**

In *Hard Times* [1], Charles Dickens provided a caricature of teachers and schooling in 19<sup>th</sup> Century England. His schoolmaster insists that teachers must stick to teaching facts: "Facts, teach these boys and girls nothing but facts. . . . Nothing else will ever be of any service to them."

In sharp contrast to this view of the role of teachers is Albert Einstein's perception: "The most important thing for a teacher to impart to the children is not information and knowledge but rather a longing for information and knowledge . . ." [2].

It is obvious that teachers must be people who have mastered the facts they teach. Our culture increasingly demands that people have the ability to organize information precisely and transfer it rapidly.

Our society requires more of educators, however. Einstein's call for teachers who inspire a yearning for knowledge continues to be important. Preparing people to become competent in facts and skills, proficient in teaching, and able to lift the vision of their students is a humbling charge for higher education.



In the late 1980s, the state of Virginia began requiring that teachers have a major in one of the liberal arts and sciences rather than in education. Students entering Longwood College at that time could select a major to any of the disciplines. By adding to that major specified professional studies courses and field experiences, these students became licensed to teach in the elementary and middle schools of Virginia. The College soon found, however, that our students were not as prepared as we thought necessary to teach mathematics, natural sciences, English, and social studies, since the only courses they were required to have in those disciplines were at the General Education level.

The Liberal Studies Major described here was designed to give students a background broad enough in these disciplines to be able to teach all of them at the elementary level. The College also wanted to provide background extensive enough for these students to be able to teach two disciplines at the middle school level. When Virginia created the Standards of Learning for the disciplines at each grade level, Longwood's Liberal Studies Major was revised to ensure that all of the SOL were covered in the content studied by students in the Teacher Preparation Program.

### **General and Content Studies**

Acknowledging the need for elementary and special education teachers to have more extensive backgrounds in mathematics, natural sciences, social sciences, and humanities beyond the general education requirements, a cross-disciplinary team from the School of Education and Human Services and from the School of Liberal Arts and Sciences designed a major tailored for the candidates. This major, designated as the Liberal Studies Major, is a fifty-four credit program that requires specific courses in the following areas: Mathematics (9 credits), Natural Sciences (15 credits), Social Sciences (12 credits), Humanities (15 credits), Electives (3 credits). When general education and liberal studies major requirements are combined, teacher candidates complete a total of twenty-one credits of English (grammar, literature, and writing); eight credits in fine arts and humanities; twelve credits of mathematics and computer science; nineteen credits of natural sciences; and twenty-one credits of history and social sciences. These requirements ensure that teacher candidates have a broad general studies background in the various content areas of the elementary school plus the depth of studies required for the middle school.

Teacher candidates in elementary education take an additional forty credits in professional studies and field experiences for the Bachelor of Arts or Bachelor of Science Degree. This prepares them to meet the requirements for professional licensure in PreK-8. Teacher candidates in special education complete forty credits of professional studies and field experiences at the undergraduate level and 36 credits at the graduate level. The graduate year in special education includes coursework in regular and special education.

Secondary education programs are currently under review relative to the new licensure regulations passed by the Virginia Board of Education in May of 1998. Longwood College foresees the revision of the Modern Languages 8-12 program to meet the new requirements for Modern Languages Pre K-12. The History and Political Science 8-12 programs will be revised to meet the licensure requirements for History and Social Sciences 6-12. Although the licensure regulations for other programs do not vary greatly from the programs currently offered at Longwood, all programs will be reviewed to ensure their compliance with the new state regulations.

### **Professional and Pedagogical Studies**

Students majoring in Liberal Studies are required to have the following courses in the professional component of the teacher preparation studies:

- Introduction to the Teaching Profession (1 credit)
- Human Growth and Development (3 credits)
- Methodology - Reading and Curriculum and Instruction (12 credits)
- Measurement & Evaluation (1 credit)
- Classroom Management (2 credits)
- Instructional Technology (2 credits)
- Survey of Exceptional Students (2 credits)
- Education Seminar (1 credit)

Two factors have already enhanced the technology competencies of teacher candidates at Longwood College. The first is the new professional education facility, the Hull Building, which was completed in the Summer of 1996. The second is the requirement of a computer science course as part of the mathematics component of the liberal studies curriculum. A third factor is having an even greater impact: the requirement of personal laptop computers for all

students.

Since Longwood restructured its curricula in the 1980s, its teacher preparation programs have required a course entitled, "Media and Computer Technology Module." The course is a requirement during the professional semester, prior to student teaching. While this idea was excellent from its inception, the lack of technology available in the professional unit and the lack of prior experience in the college career of teacher candidates made this course difficult to implement. In 1996, the Department of Education, Special Education, and Social Work moved into a new facility equipped with the advanced hardware and programs that allow for the preparation of teacher candidates who are truly able to use technology efficaciously in their classrooms. This development, combined with the fact that candidates now entering Longwood are more literate in the use of technology than their predecessors, results in teacher candidates who are genuinely competent to use technology in their teaching, and otherwise in their professional roles. With "Introduction to Computer Science" as a mathematics requirement in the Liberal Studies Major, all teacher candidates now have experience with techniques of structured programming, algorithms, problem solving, and applications.

In the Spring of 1998, Longwood College made the decision to require all incoming students to have their own computers. The College supports numerous computer labs on campus for student and faculty use. Students are required to own a laptop computer that contains the same basic software as all College office, classroom, and lab computers. All dormitories on the campus have network connections. Students have, therefore, Internet and email access from their dorm rooms. Technical support is provided by the computer vendor and resident technology assistants. The Office for Instructional Technology for Teaching and Learning hires, trains, and maintains eighteen technology assistants who are assigned to dormitories for the sole purpose of training and supporting students in their technology needs. The 250-300 incoming teacher candidates each year are provided a rich background in technology before they reach the professional semester where the Media and Computer Technology Module is taught.

### **Field Experiences**

Field experiences continue to be a cornerstone of the Teacher Preparation Program at Longwood College. Teacher candidates in the elementary and special education programs

enroll in two practicum experiences prior to the professional semester when they student teach. Secondary teacher candidates also enroll in two field experiences prior to the professional semester. All candidates entering the teacher preparation program for secondary education enroll in practica focused primarily on observation and teacher aid activities, and a second practicum focused on planning and implementing instruction.

### **Professional Community**

An exciting aspect of the Liberal Studies/Elementary and Liberal Studies/Special Education Majors at Longwood College is the collaboration that takes place among faculty in the School of Liberal Arts and Sciences and the School of Education and Human Services. The Director of the Liberal Studies Program is a faculty member in the School of Liberal Arts and Sciences. The Liberal Studies Advising Coordinator is a faculty member in the School of Education and Human Services. The Liberal Studies Steering Committee consists of faculty leaders from both schools. All curricular decisions regarding the major are made by this faculty body. Annual workshops are offered for all faculty in the two schools who teach in the Liberal Studies major. Advising of teacher candidates in these programs is carried out by faculty from both schools. This collaboration results in the ownership of the elementary and special education teacher preparation by the entire College.

The spirit of cooperation and collaboration in the College and in the School of Education and Human Services has increased. As revised licensure regulations and endorsement areas have been developed by the Virginia Board of Education, more interaction has occurred between School of Education and Human Services and the curriculum committees of the various departments offering majors associated with secondary teaching licensure. This kind of collaboration can only continue to strengthen the teacher preparation programs of the College.

### **Future Directions**

The immediate future of the School of Education and Human Services at Longwood College will include a number of specific activities:

- A number of faculty appointments will become available in the next several years. The faculty will be examining the best use of these positions and will be making recommendations to the Dean concerning revised definitions of the faculty positions that

are available and appropriate reconfiguration of teaching resources. The needs of pre-professional students and teachers with continuing professional development needs will be considered. The projected need of the Commonwealth of Virginia for teachers will also be a factor in this decision making process.

- A task force of the faculty will be formed and charged with the responsibility of developing recommendations for the creation of the Longwood Educators' Network. The Network will be established by technology links to all partner schools in the Commonwealth who work with Longwood College in providing practica and student teaching placements. The Network will allow for more frequent and convenient communication between students in field placements, their cooperating teachers, their field supervisors, and the Longwood faculty.
- The Longwood College Teachers for Tomorrow Program has been established in eight high schools in the Southside Virginia region. This program for high school juniors and seniors encourages competent, committed students to consider teaching as a profession and Longwood as the institution of choice for pursuing that profession. These students will participate in a credit-bearing elective course, observe and participate in public school classrooms, learn about career opportunities in education, and receive information about scholarships and other college support options including opportunities at Longwood College. The program will benefit both Longwood College and Southside Virginia by encouraging talented young people from the region to enter the teaching profession, by encouraging these talented young people to serve Southside Virginia as teachers, and by assisting Longwood College and the region in recruiting and retaining minority teachers.

In July 1997, Longwood College was accepted into the membership of the Renaissance Group. Conceived and established as an organization for Presidents, Vice Presidents, and Deans, the Renaissance Group is devoted to strengthening teacher education programs. A condition of membership is presidential involvement along with the participation of the Chief Academic Officer and the Dean of Education. The Renaissance Group has identified a set of principles for the preparation of educators. When Longwood College become a member, it endorsed the following principles as guidelines for the future of its teacher preparation programs. As the faculty, students, and administrators of the institution look toward the new

millennium, these principles will be implemented in the following ways by Longwood College:

- Longwood will continue to be committed to the principle that the education of teachers is an all-college responsibility.
- Longwood will continue to value quality teaching above all else in the preparation of educators.
- Longwood will continue to integrate the preparation of teachers throughout the collegiate experience. Early and continued involvement in schools will also continue to be central to the program.
- Longwood will continually examine its curriculum and make changes to that curriculum as the needs of students and schools change.
- Longwood will maintain rigorous entrance and exit requirements of its teacher preparation candidates.
- Longwood will continue to be committed to preparing teachers who are competent in teaching methodologies, teaching content areas, and in the understanding of the needs and characteristics of learners.
- Longwood will continue to be dedicated to preparing teachers from diverse backgrounds to teach in an equally diverse society.
- Longwood will continue to support and encourage its teacher preparation faculty in their scholarly and professional endeavors.
- Longwood will remain committed to providing quality continuing education to teachers.

■

## References

- [1] C. Dickens, *Hard Times*, Chapman and Hall, London, 1868.
- [2] A. Einstein, "To National Council of Supervisors of Elementary Science," Einstein papers, Princeton University, July 3, 1934.



## A NEW INTERDISCIPLINARY MATHEMATICS AND SCIENCE COURSE

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As Norfolk State University has been considering how to adequately prepare students to teach the challenging new mathematics and science called for the Virginia Standards of Learning [1], we have reached the conclusion that the student programs need to provide interdisciplinary experiences linking mathematics and science. We reached the conclusion for two reasons. First, even with the larger number of courses called for in the new licensure regulations, there are not enough course hours available to teach all of the different mathematics and science topics that future teachers need to have studied. Second, elementary and middle school students do not study science and mathematics organized in the same way as these topics are organized in universities. Rather, students are interested in, and study, broader topics such as the working of the human body or the structure of a broad ecological system. In order for teachers to teach these subjects in this way, making use of the appropriate mathematics behind these structures, they must have themselves studied these topics in this manner. The new course, *Interdisciplinary Mathematics and Science*, that has been developed at Norfolk State University, provides students with an interdisciplinary background, then requires each student to study a broad interdisciplinary topic as a member of a team, and then to prepare oral and written presentations on this topic. The course, and the experience of students with this course, will be described in this paper.

As institutions across the state of Virginia struggle with the problem of preparing students to teach the challenging new mathematics and science called for in the Virginia Standards of Learning (SOL), it is becoming clear that there are not enough course hours available to teach future teachers all of the different mathematics and science topics implied in the SOL. We at Norfolk State have concluded, therefore, that programs for intending teachers need to provide more interdisciplinary experiences linking mathematics and science. Moreover, students preparing to teach elementary and middle school will not deal with mathematics and science in their classrooms in the same isolated way that these topics currently are presented in university programs. Rather, students at these levels study broader science topics related, for example, to the human body or to the environment, in which mathematics tools and concepts emerge in a natural way. In order for teachers to teach these subjects from such an interdisciplinary perspective, they, themselves, should study these topics in a like manner.

One attempt to address the problem at Norfolk State consists of the development of a new



course, *Interdisciplinary Mathematics and Science*, a course which integrates mathematics and science investigations in a mathematical modeling setting. In this course, students work in cooperative groups on solutions to real world science problems and then present their findings in oral and written presentations. The purpose of the course is to involve students in the basic tools and concepts of mathematics (graphing, equation solving, curve fitting, computational analysis, etc.) within the context of interesting and challenging science problems, and with a strong emphasis on developing students' writing skills. The course is team-taught by faculty from the mathematics and science departments and uses written modules developed under the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) program funded by the National Science Foundation. The prerequisites for the course are two semesters of college mathematics and two semesters of laboratory science. Thus, the course can serve as a lower level mathematics or science elective and can be particularly useful as a supplementary mathematics/science enrichment course for intending teachers.

The course begins with a brief introduction which provides students with an interdisciplinary background and an initial experience with mathematical modeling principles. Thereafter, students work in small groups on four investigatory modules, each dealing with a broad science topic, as described below, under the guidance of members of the teaching team. The modules provide background information on the topic, and they lead students, by way of a sequence of questions, to solve problems associated with the broad topic. Students use the Internet and the campus library, visit the science laboratory, or sometimes take a field trip in pursuit of answers and solutions. Their findings contain expositional, tabular, graphical, and symbolic elements, are typed on a word processor, and are presented orally to the entire class using modern technological aids. Each student is expected to demonstrate on written examinations knowledge of basic mathematics and science principles underlying each of the modules.

### **Description of Course Modules**

**Module 1: The Quality of Water.** This module addresses some causes and remedies of water pollution in the Hampton Roads area. A lecture by a representative of the Chesapeake Bay Foundation (CBF) and a visit to a local water treatment plant provide background material and data for this unit. After their visit to the treatment plant, students go into the

chemistry laboratory and create scaled down models of water treatment processes that they witnessed at the water treatment plant. They also perform water-cleansing experiments on water samples that they collect from local waterways. Using data from an oyster harvesting experiment being conducted by the CBF, students use spreadsheet analysis to make projections concerning the future oyster population in selected tributaries around the Chesapeake Bay. The module concludes with an exercise in which students use regression analysis on data collected by the United States Geological Survey to determine PCB and turbidity levels in certain rivers as functions of river depth.

**Module 2: Epidemics and the Spread of Diseases.** In this module, students are provided background and data on some of the dread diseases which plague our society along with information on some of the epidemic outbreaks of the diseases. Students use the Internet extensively in this module to gather information about historical epidemics dating back to the 14<sup>th</sup> century and to catalogue recent outbreaks of E coli, Ebola, and AIDS. They are held spellbound as a faculty team member from the Biology Department presents a slide presentation telling the story of the initial outbreak of Ebola in Zaire. A similar lecture on the HIV virus is given by a faculty team member with expertise in health science. After students are introduced to the SIR model for the spread of disease, they apply the model to data relating to the Plague of Bombay in 1905 and the Ebola Outbreak of 1995. They also use data published by the Centers for Disease Control and curve fitting techniques to try to identify trends in the incidence of AIDS cases in the United States and to predict future trends. The module ends with an investigation on viral loading.

**Module 3: Heat Loss and Gain.** This module begins with a discussion of the problem of heat escaping from homes and other shelters and the use of thermal insulation to combat the problem. Students are introduced to Newton's Law of Cooling by way of experiments in the physics laboratory involving the cool down rate of hot water. The same experiment is modeled in the classroom using a Texas Instruments Calculator Based Laboratory and curve fitting techniques. In a final challenge, students create a model for insulating a house and then test a strategy for cost effectiveness in selecting insulating material.

**Module 4: Human Genetics.** In this module students are introduced to elementary principles of genetics and the application of these principles to the study of certain genetic

diseases and other genetically based phenomena. The genetics principles are introduced through individual examples using intuitive probability notions. This approach extends in a natural way to discussions of population genetics and illustrations of the Hardy-Weinberg Principle. Students examine case studies involving genetic diseases such as cystic fibrosis, Huntington's disease, Tay-Sach's disease, albinism, and sickle-cell anemia. They obtain firsthand information about the research efforts at Eastern Virginia Medical School to isolate a diabetes gene, and, after viewing a PBS video, they discuss the ethical implications of the discovery of a breast cancer gene. The module involves students in an experiment comparing blood type frequencies on Norfolk State's campus with established blood type proportions in the United States and elsewhere. Their final challenge is the gathering of information on the Internet about the Human Genome Project.

### **Results of Initial Pilot Testing of the Course**

We began pilot testing our course during the spring semester of 1997. Getting a new course started is always difficult, but after some innovative advertising and some good natured "arm twisting", we were able to get 19 students enrolled in the initial offering of the course. The mix included 17 undergraduates and 2 graduates, of whom 5 were applied mathematics majors, 6 were mathematics education majors, 6 were computer science majors, and 2 were engineering majors. The composition of the enrollees, in effect, contributed to the interdisciplinary flavor of the course. Subsequent offerings of the course (two to date) have included elementary education majors and biology majors. One of our proudest accomplishments is the fact that no education major has failed or withdrawn from the course. This supports our belief that interdisciplinary courses like ours can be used to prepare intending teachers for the implementation of the SOL in mathematics and science.

Our initial evaluation of the course was based on three items: a) student participation in group activity, b) student performance on examinations covering basic mathematics and science skills, and c) student evaluation questionnaires. Student evaluation surveys were conducted after the completion of each module, and one final questionnaire was administered at the end of the course. Similar final questionnaires were administered in three traditional sophomore/junior level courses in mathematics, biology, and chemistry, each taught by a member of our teaching team.

We found that students, after an initial period of adjustment, adapted very well to working in cooperative groups. In order to discourage students from depending on one or two persons in the group to do all of the work, we required a "division of labor" statement to be included with each of their submissions. Students soon realized that each had to contribute his/her expertise in order for his/her group to successfully complete a module.

Relative to item b), we identified items on the final examination which appeared to deal with basic mathematics and science concepts and skills. We did the same in the three regular courses. We found that performance on these items in the interdisciplinary course was comparable to that in the three regular courses. Our conclusion is that the innovative, experimental elements in the course are not detrimental to the basic skill building that should accompany a mathematics or science course.

As a result of our evaluation surveys, we found that students in the interdisciplinary course displayed great enthusiasm for the course topics and methodology. They appreciated the relevance of our modules to real world problems and issues, and they were amazed at the interconnectedness of the disciplines. We discerned a definite increase in students' confidence in their ability to do mathematics and science as measured by their readiness to tackle challenging problems. By far, the field trips were cited as most enjoyable. The novelty of having more than one instructor was seen as very beneficial, especially in regards to instructor accessibility. The students in the interdisciplinary course were unanimous in citing as advantageous the working together in cooperative groups. On the negative side, the students thought that we attempted to cover too much material and thought that they could have gone into more depth on particular topics if time permitted. The latter judgement suggests that perhaps a follow up course should be considered.

## **Conclusion**

The development and revision of the content and methodology of our new course is continuing under the umbrella of the VCEPT Program. We have obtained good exposure for the new course on Norfolk State's campus, and we have received some inquiries about the course from some neighboring universities. An indication that the course will be sustained after the grant period is the fact that the School of Science and Technology has included our course in its approved list of electives. Two departments in the School are permitting its

students to take our course in lieu of other requirements. Moreover, the School of Education is considering our course in a list of courses to be recommended for additional mathematics and science credits to meet the new state licensing requirements. We feel that the ultimate measure of the success of the course will be its ability to convince students, education majors and others, that they can do mathematics and science and that learning mathematics and science can be an enjoyable enterprise. By this measure, we think we have made a pretty good start toward success. ■

### Reference

- [1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.

## HIGHER EDUCATION'S GREATEST CURRENT OPPORTUNITY AND RESPONSIBILITY

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Preparing the next generation of teachers at all levels from kindergarten through college is higher education's greatest current opportunity. Getting it right may be our greatest challenge. The face of science and technology is by definition changing constantly. Today, many feel that the most important work in science is going on increasingly at and across the interfaces of the traditional discipline. To serve our society well, education in the sciences, mathematics, engineering, and technology must change accordingly.

In my view, curricula at all levels (K-16) too often continue to reflect only the narrow traditional disciplinary approaches that science has taken in the past, in part due to the existing political structures within academe. Teachers should both appreciate and have understanding of the interdisciplinarity of scientific thought and technological application. I propose that the preparation of all future elementary school teachers contain an interdisciplinary emphasis encompassing all the sciences including mathematics; and that middle and high school science and mathematics teachers' training be largely interdisciplinary in nature as well.

The preparation of America's next generation of elementary, middle and high school teachers is higher education's greatest current challenge and responsibility. The data have convinced us that this is true for teachers of science and mathematics, and it appears to be so in other areas as well.

Within the last several months an array of national public figures and groups has called attention to this issue, and maybe, just maybe, higher education is beginning to respond; but it is not so clear that the seriousness of the response is commensurate with the seriousness of the situation.

President Clinton told the annual meeting of the NAACP in July 1998 of the need for more qualified college graduates to go into teaching, and in particular the need for minority teachers to serve as role models for inner city students. U. S. Department of Education Secretary Riley has said that "In the next ten years, we need to hire two million teachers to replace a generation of teachers who are about to retire, and to keep up with rising

enrollments," and the National Commission on Teaching and America's Future has reported that more than half the teachers who will be teaching ten years from now will be hired during the next decade.

Our concerns extend to all of the areas of teaching, but the need for improved education of teachers in the scientific and mathematical disciplines is especially acute. Although there do exist many fine teachers who are well qualified in the sciences, their numbers are small within the total need, especially at the elementary school level. At the middle school level, the majority of these teaching science or mathematics did not complete majors or minors in the areas in which they are teaching. At the high school level, too often teachers whose training is largely in the life sciences are certified to teach physical sciences.

The opportunity that this serious deficiency presents higher education, and in particular the science and mathematics departments, is clear. College and university science departments, especially the physical sciences, are increasingly coming under attack by budget cutters as being too expensive, and having too few students to warrant majors programs. And it is all too true that Physics and Chemistry departments' undergraduate halls often echo with few footsteps after the students who are taking the lower division service courses, e.g. engineering students and pre-health careers students, leave the building.

But the budget cutters aren't the only ones complaining. Even the service courses need work according to Engineering and Life Sciences Departments, which increasingly are teaching mathematics and physical science to their own majors to assure they get the subject matter desired. For example, some engineering schools are now requiring only one quarter of chemistry from the chemistry departments.

Nor is the content of courses the only concern. In a recent study often cited, "Talking About Leaving", Seymour and Hewitt found that many science majors who drop out of science say it is because of poor teaching. But perhaps even more telling is the finding of the same study that students who stayed in and majored in science also complained about poor teaching.

Ironically, then, the societal need for future teachers with quality undergraduate science

and mathematics preparation comes at a good time in that it provides a great opportunity for these nearly empty science departments to fill up their upper division courses with a "new" major, those who will become teachers. This could rejuvenate many departments, perform a much needed national service, and as an added bonus probably end up being a recruiting device for traditional majors.

But this "solution" is far from simple. What is NOT needed are curricula designed for students expected to become scientists; such curricula have dominated science and mathematics undergraduate curriculum design for much of U.S. education history. What is NOT needed is for a department to assign one or a few individual faculty (who have fallen on hard times) who will reluctantly look after a less than favored set of students.

What is NOT needed are individual science departments approaching this issue totally independently from the other sciences and from the colleges of education. What is NOT needed are faculties who disparage careers in teaching, and who discourage their better students from moving in any direction other than toward the Ph.D.

What IS needed are curricula designed to provide future teachers with a reasonably quantitative as well as descriptive background in science and math, but that have a highly multi- and interdisciplinary character. Further, the fledgling teachers also must bring away from their education specific science materials and aids appropriate to the level they will teach to take directly into their future classrooms.

What IS needed are whole science and mathematics departments (not just an occasional interested person) willing and wanting to completely rethink their curricula aiming primarily at the needs of the majority of students who will not be moving toward Ph.D.s, or even other science majors, who will work together across the disciplines. What IS needed are faculty who are themselves teaching role models, who have learned to enrich their traditional roles as lecturers, e.g. using inquiry and group learning, especially at the lower division levels. What IS needed is a mobilization of the faculties of whole colleges of arts and sciences working collaboratively with each other and with their colleagues in colleges of education.

The complexity of the problem and its solution sometimes are daunting. Much of this is



vested in the territoriality that is so characteristic of much of academe. First, comes the need for faculty from the several sciences to collaborate. What many science faculty do not realize is that even secondary school teachers, let alone elementary teachers, rarely get to teach a single discipline in their careers. For just that reason (there are other, obvious, more substantive reasons) a multi-disciplinary teacher preparation curriculum is needed. Further, most of the undergraduate students who represent potential teachers will be found hanging out in the life sciences departments, whereas the greatest need is for the more quantitative preparation in chemistry, physics, mathematics, and engineering.

But the problem of communication among the scientific disciplines pales when compared to the communication problems that exist between the sciences and the colleges of education. In our view, it is essential that these entities work together if we are to achieve a truly good national system of teacher preparation. Yet, the norm even at traditional teacher training institutions is more nearly that of armed camps and fortress mentalities, than collaboration. At best, it seems a faculty member or two from each side will have good personal relations and contact with the other. But the needed systemic, institutional approach is indeed rare.

This conflict between colleges of education and colleges of arts and sciences was made almost laughingly clear at a meeting that the National Science Foundation and the American Association for the Advancement of Science collaborated on in 1995. We convened about 100 deans of both education and arts and sciences in Washington to provide an opportunity to seek ways for their collaboration. There we learned that some of these deans from the same campuses met each other for the first time at the meeting in Washington!

Fairly or not, in recent years higher education, especially the research universities, have come under increasing scrutiny and fire from the public and from state legislatures. It was reported in the *Chronicle of Higher Education* that many state legislators and policy makers believe that public colleges and universities care little about undergraduate education, especially education at the freshman and sophomore levels.

This unhappiness is not focused exclusively on the research universities. Recently, the school superintendent of a small city related that he had given up asking for help from his regional state university (formerly teachers college), where most of the teachers are prepared,

and found much better responsiveness from a nearby church related private college.

Rumblings in the U.S. Congress have already begun. Writing in the April 24, 1998 issue of the Chronicle of Higher Education, George Miller of California has accused university teacher training programs of perpetrating "fraud" both on the public and on the future teachers who think they are being properly trained. Even more recently in the May 15, 1998 issue of the Chronicle of Higher Education, Jeff Bingaman of New Mexico says he would deny Federal student-aid money to universities whose graduates can't pass state licensing exams. I believe that academe's serious attention to the problem of teacher education could be a major antidote to this growing disaffection with higher education on the part of public officials, which has not yet come to its fullness. Indeed, when state legislatures as well as the U.S. Congress come fully to comprehend that the key to success in improving teaching in the schools lies in the colleges, far harsher legislative mandates than yet seen are inevitable.

It would be incorrect to imply that no good models for change exist: there are; or that attention in the colleges isn't increasing: it is. I am very interested in learning about the models for change that are being developed in Virginia. For example, the bachelors degree in interdisciplinary science that is being developed at Virginia Commonwealth University includes many of the interdisciplinary components that I described earlier. With some modification, I think that the degree would provide excellent preparation for all high school science teachers. The add-on interdisciplinary science program that Longwood College is discussing would provide excellent preparation for prospective middle school teachers. The interdisciplinary course being developed and offered by Norfolk State University and the capstone interdisciplinary sequence that is proposed for future teachers by the University of Virginia are examples of the types of experiences that are crucial for all future teachers.

Much of the work taking place in Virginia and elsewhere is being supported by the NSF Collaboratives for Excellence in Teacher Preparation Program (URL:<http://www.ehr.nsf.gov/EHR/DUE/start.htm> or E-mail:[undergraduate@nsf.gov](mailto:undergraduate@nsf.gov)). This program supports major reform projects that do involve collaboration among the scientific disciplines and with colleges of education, who do work together to produce multi-disciplinary curricula, new tools for fledgling teachers, and a rigorous but hospitable environment for the students. They also involve collaboration among the major teacher preparation institutions, including research

universities and community colleges, within an appropriate region. These projects are outstanding examples of solutions to the complex problem of teacher preparation. Nonetheless, they represent only a small piece of what needs to take place if higher education is to realize this opportunity.

If the opportunity that teacher preparation presents to higher education isn't sufficient, let's consider the responsibility side. No matter what higher education does -- whether the colleges and universities do everything they can and should do or whether they do nothing, one thing is certain: every classroom in America will have a teacher; no classroom will operate without a teacher; everyone of those millions of teacher positions that come open are going to be filled. They may be filled with bright people, well-prepared in their disciplines, and well-equipped with the best teaching and learning techniques. Or they may be filled with others; but they will be filled.

The quality of those millions of future teachers, as of the existing teacher corps, is the responsibility of higher education. It's also an opportunity. ■

## **THIRD INTERNATIONAL MATHEMATICS AND SCIENCE STUDY (TIMSS) AND THE NATURE OF COLLEGE COURSES**

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The TIMSS report leads to some strong conclusions concerning the effectiveness of various approaches for teaching mathematics and science in grades K-8. This presentation will focus on a description of the findings of TIMSS concerning effective teaching. Although the TIMSS study and its findings relate directly to teaching prior to college, the findings do have a lot to say about effective teaching at the college level. At the very least, they describe the type of teaching and learning that future teachers must experience if they are to bring about this type of learning in their own courses.

The Third International Mathematics and Science Study (TIMSS) is the most comprehensive international education comparison ever undertaken. During 1995, data were collected from a half-million students in 41 countries. The TIMSS was designed to accurately compare achievement in science and mathematics across the nations that participated in the study. Student tests, questionnaires, videotapes of teaching, and curriculum materials were analyzed. The entire assessment process was established and rigorously scrutinized by an international review committee to ensure the validity and reliability of the study [1, 2, 3, 4, 5].

The TIMSS is only one study, but balanced with findings from other research it can provide insight into teaching and learning. This article will summarize the findings from the multiple TIMSS reports and suggest implications for college level teaching in science, mathematics, and education courses.

### **Achievement**

The TIMSS achievement data show that U.S. student performance, relative to other countries, decreases in mathematics and science as students progress through school (see Figure 1, following page). In addition, U.S. students score better in science than mathematics at all grade levels.

- In fourth grade, U.S. students score among the highest nations in science and above the international average in mathematics.

- In eighth grade, U.S. students score slightly above average in science and slightly below average in mathematics.
- By twelfth grade, U.S. students are among the lowest scoring nations in both science and mathematics.

	Grade 4 n=26	Grade 8 n=41	Grade 12 n=21
Science international average	above	above	below
Mathematics international average	above	below	below

n=number of countries in the study

**Figure 1. TIMSS U.S. Achievement for Grades 4, 8, and 12.**

Each test assessed multiple content areas within mathematics and science. In mathematics, the content areas with greatest achievement are data analysis and lowest achievement are measurement and geometry (see Figure 2, below).

	Grade 4	Grade 8	Grade 12
Above	data analysis geometry patterns numbers		
Average <i>—international average—</i>	fractions ————— measurement	data analysis fractions algebra ————— proportionality	(AP calculus) ————— (calculus & AP calculus)*
Below		geometry measurement	general knowledge advanced mathematics numbers/equations calculus geometry

\* (U.S. Advanced Placement calculus and calculus students compared to other advanced mathematics students)

**Figure 2. U. S. achievement on mathematics content areas.**

In science content areas students score highest on environmental science and have the greatest difficulty with the physical sciences (see Figure 3, below).

	Grade 4	Grade 8	Grade 12
Above	environmental science earth science life science physical science	environmental science	
Average  ---international average---		life science earth science chemistry physics	
Below			general knowledge physics heat, modern physics, waves, mechanics, electricity/magnetism

**Figure 3. U.S. achievement on science content areas.**

### Teachers

There are differences in the structure of the teachers' school day and the training they receive.

- Japanese teachers have more time scheduled for planning during the school day than do U.S. teachers, consequently they have more students in each class to teach.
- Teachers entering the profession in Japan and Germany participate in a long-term apprenticeship program.
- U.S. teachers tend to have more college education than teachers in other countries.

### Student characteristics

Initial investigation of the contextual factors in students' lives reveals little relationship to student performance in science and mathematics especially at the fourth and eighth grade levels. The study indicates that U.S. students in grade 12:

- Watch as much TV (1.7 hours per day) as students in other nations,
- Work more at paid jobs outside the home (61% compared to 28% internationally) and work longer hours per day (3.1 hours compared to 1.2 hours),

- Take less mathematics and science with many U.S. states requiring only 2-3 years of mathematics and 2 years of science in the four years of high school, and
- Report doing less homework than students in other countries.

### **U.S. curriculum**

The U.S. does not have a national curriculum, which is unlike most other TIMSS countries. When compared to curriculum in other countries, the U.S. curriculum:

- Lacks focus,
- Canvases more topics in less depth (often described as a mile wide and an inch deep), and
- Contains are less advanced topics.

### **Delivery of instruction**

The videotape study of classroom instruction includes only grade eight mathematics teachers from the U.S., Japan, and Germany. The videotapes reveal differences in the structure and delivery of lessons, kind of mathematics taught, kind of thinking students are engaged in during lessons, and teachers' view of reform. Japanese students score higher in achievement on the TIMSS than do students from the U.S. and Germany. U.S. and German students' scores are not significantly different.

*Structure and delivery of lessons.* In the U.S. and Germany, instruction is primarily based on problem solving, whereas in Japan it is on understanding. In the U.S. and Germany, lessons focus on developing skills and progress from an initial acquisition phase to an application phase. In Japan lessons focus on understanding the thinking behind concepts and progress from problem solving, to student sharing of solution methods, to jointly developing understanding of concepts.

U.S. lessons were less coherent as teachers switched between topics more often, covered more topics, provided few connections between topics, spent time on irrelevant diversions, and were more frequently interrupted by outside events. U.S. students spent more time in class reviewing or doing homework.

*Kind of mathematics taught.* U.S. lessons were less advanced when compared to the grade level that topics were taught in other countries, concepts were stated as opposed to being

developed, and no lessons were assessed to be in the high quality category in a blind review of (low, medium, or high) lesson quality.

*Kind of thinking students engaged in during lessons.* U.S. and German students spent approximately 90% of their time practicing routine procedures compared to 41% for Japan. Japanese students spent 44% of their time inventing new solutions and engaging in conceptual thinking. Student-generated alternative solutions to problems were three times more likely to be part of Japanese lessons than U.S. or German lessons.

*Teachers' view of reform.* The *Curriculum and Evaluation Standards for School Mathematics* [6] and the *Professional Standards for Teaching Mathematics* [7] outline the National Council of Teachers of Mathematics recommendations on how to teach mathematics. Japanese teachers appear to be teaching more in line with these standards than U.S. teachers. When asked, U.S. teachers claim to be following the current thinking about effective mathematics teaching and learning. They justify their claims with more superficial reasons such as using manipulative and cooperative learning than with teaching for understanding. The videotape study suggests that having standards is insufficient for changing practices in the classroom and that developing a common understanding of what quality teaching looks like is needed.

### **Future TIMSS data**

The TIMSS-R, which is a partial repeat of the 1995 study, is being conducted in the spring of 1999 for grade eight students. These are the same students who were in grade four in 1995 during the original TIMSS. In addition, a videotape study is being conducted for grade eight science teaching. As this information and further analysis of the original massive TIMSS data set become available, they will provide further insight into teaching and learning in the U.S. and in many other countries.

### **Implications for college courses**

Many of the findings about curriculum and instruction in the TIMSS reports also apply to college teaching. Among the implications for college science and mathematics courses is the need for faculty to understand education research in order to provide effective instruction for all students. In order to accomplish this, professional development is needed for faculty



to enable them to recognize the underlying principles of quality teaching and deliver this kind of instruction in their courses. Since pre-college teachers tend to teach in the same way they were taught, college faculty need to model effective teaching and learning in their courses for teachers. Since the faculty themselves probably did not participate in this kind of instruction when they were students, they will need long-term professional development and support in creating an environment in their own courses that maximizes student learning.

Therefore, collaboration among faculty in education, science, and mathematics is needed as they all learn about the TIMSS, other research findings on effective teaching, and seek to implement the findings in their own teaching. This will be a great challenge for college administrators to support, because teaching is not always valued and rewarded equally with research in science and mathematics. Establishing a long-term dialogue about teaching among faculty is key, as they grapple with the process of change and the discomforts and joys associated with change. Education faculty can facilitate this process for other faculty members by synthesizing the research about effective teaching, developing learning experiences to facilitate productive change, and supporting the change process for faculty in science and mathematics. The dialogue needs to produce and support quality teaching. In addition to critically analyzing research on effective instruction, a focus on conducting research on students' learning in their own classes may provide a basis for productive discussion and change.

If K-12 teachers are going to establish learning environments in their classrooms that foster students' understanding of science and mathematics, then they will need to participate in effective teaching and learning, collaborate with colleagues on a long-term basis to understand the underlying principles, and conduct research on their own classes to see what works with their students. Faculty can play a critical role in this process not only in helping them to understand science, mathematics, and education but also in helping teachers to conduct research on their teaching. ■

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## **TEACHING AND LEARNING SEMINAR FOR SCIENCE AND MATHEMATICS FACULTY**

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A yearlong seminar for science and mathematics faculty to investigate teaching and learning is in its second year at George Mason University in Fairfax, Virginia. This article describes the seminar and preliminary findings from the first year.

The yearlong seminar is a joint effort of the science, mathematics, and education departments. The purpose of the seminar is to foster a discussion among faculty about effective teaching and learning in order to enhance understanding of research-based teaching and assessment practices. In addition, it is to provide support as faculty reflect on their own teaching and try to develop strategies to reach all students.

### **Seminar design**

#### **Participants**

The seminar was open to all science and mathematics faculty and participation was voluntary. In year one there were ten participants, five males and five females. The participants ranged from second year faculty to veterans of many years, including one department chair. In general, the female faculty members were younger and had less experience at the university level than their more senior male colleagues in the seminar.

#### **Logistics**

The seminar met twice a month from September to May for three-hour sessions. For their participation, faculty members received a \$1000 stipend. They also received approximately one book a month that was tied to seminar topics.

George Mason University is located in the northern Virginia suburbs of Washington, DC. The university has 25,000 students and 850 faculty. Over 100-degree programs are offered from the bachelor to the doctoral level.

### Seminar leader

The seminar discussion leader is a science educator in the Graduate School of Education. She set the agenda, shared research on teaching and learning, and facilitated faculty discussions. She has taught both education courses and chemistry courses at the college level. In the first year of the project, she conducted the seminar in addition to her regular teaching load.

### Seminar topics

In addition to exploring research on new topics each session, the faculty members shared their own experiences in teaching. This sharing was extremely important to participants who seldom had the opportunity to discuss teaching. The seminar topics included:

- multiple intelligences and learning styles,
- cooperative learning in large lectures and small classrooms,
- questioning strategies and wait time research,
- *Third International Mathematics and Science Study* (1996 [1], 1997 [2, 3], 1998 [4]),
- gender equity in the classroom and meeting the special needs of students,
- science and mathematics sections of the *Standards of Learning for Virginia Public Schools* (1995) [5],
- *National Science Education Standards* (1996) [6] and *Curriculum and Evaluation Standards for School Mathematics* (1989) [7],
- inquiry-based laboratory and mathematics activities,
- calculator-based and conferencing technology,
- multiple forms of assessment,
- rubrics and grading, and
- testing and evaluation.

Outside of the seminar the faculty members were expected to try many of the strategies discussed. When they returned to the next seminar, they shared their successes and areas of concern. Group problem solving, sharing, and encouragement soon became the norm. Half way through the year, the faculty members observed each other teaching. Positive examples of strategies discussed in the seminar were shared at the next meeting.

## Findings

### Reasons for attending the seminar

During the first seminar meeting, the faculty shared why they chose to attend the seminar. The two themes that emerged were a desire to:

- Know how to get students interested in learning and in the process improving their basic mathematics and science skills; and
- Expand their knowledge of instructional strategies including learning about models of appropriate practice.

### Seminar evaluation

In an end of course survey the participants were asked four questions:

- What were the most helpful aspects of the seminar for you?
- What were the least helpful aspects of the seminar for you?
- Is the seminar worth offering in the future for other faculty? Why?
- How could the seminar be improved?

**What were the most helpful aspects of the seminar for you?** The four themes that emerged from this question related to meeting other faculty, instructional strategies, new knowledge, and encouragement.

Meeting other faculty. All participants valued getting to know faculty from other departments and sharing expertise. "I found very useful the amount of discussion with colleagues on a wide variety of topics related to teaching."

Instructional strategies. A consistent theme expressed by the faculty was, "learning about different teaching strategies," "being brought up to date," "sharing ideas on teaching methods," and "learning teaching strategies that engage students more (e.g. cooperative learning)."

New knowledge. Three categories of new knowledge were terminology, reform movements, and research. In addition to learning the terminology used in the field of education, they found it especially meaningful to learn the terminology for what they were already doing in their own teaching. In general, the faculty were not familiar with the research base on teaching and learning and had little in depth knowledge of current reforms in science and mathematics education. They knew the existence of the *National Science Education Standards* (1996), *Curriculum and Evaluation Standards for School Mathematics* (1989), *Standards of Learning for Virginia Public Schools* (1995), and *Third International*

*Mathematics and Science Study* (1996, 1997, 1998), but had not had the opportunity to look at the actual reports and documents. Receiving copies of standards, reviewing these documents, and discussing them were a part of building their new knowledge of education reform. Learning about the achievement results of students in the *Third International Mathematics and Science Study* and analyzing the videotapes from the study for effective teaching strategies, provided examples of the complex nature of teaching. Building their knowledge of teaching and reform in education were areas of interest.

Encouragement. "Receiving encouragement to try various techniques" to help students learn was part of the collegial support system. As faculty got to know each other, they shared their concerns about teaching. Through group problem solving, they identified alternate strategies, commiserated on existing frustrations, and generally encouraged each other.

**What were the least helpful aspects of the seminar for you?** The scheduled time of the seminar and too many pre-college examples were the two areas that were least helpful.

Scheduled time. The timing of the seminars was problematic for many faculty. Though the seminar time and day of the week was chosen by consensus, there were conflicts as the year progressed with department faculty meetings and field research days. Finding a convenient time to meet will remain a challenge for this type of program.

Pre-college examples. A few faculty members felt that there were too many pre-college examples of teaching strategies. Perhaps there were too many examples, but when the faculty were uncomfortable with an interactive teaching strategy, they often thought of it as a pre-college strategy.

**Is the seminar worth offering in the future for other faculty? Why?** All of the participants except one felt that the seminar should be offered to other faculty members and that one person was uncertain. When responding to why the course should be offered again, one faculty member stated, "There are simply small ways in which one can adopt new strategies that are of great benefit." Another faculty member indicated that participating in the seminar "Opens up thinking to other methods and helps us analyse (sic) our teaching. It makes me think and question what I am doing, approaches I am using and has given me other areas to explore if a certain strategy is not working."

**How could the seminar be improved?** As noted earlier, meeting faculty from other

departments and sharing ideas was one of the most significant parts of the program. It was therefore no surprise that doing even more sharing was their suggestion for improvement.

### **Changes in teaching**

When the faculty met with the Dean of the College of Arts and Sciences and the Dean of the Graduate School of Education after the completion of the seminar, they indicated that the most helpful aspects of the seminar were meeting faculty from other departments and changes in their teaching. In a series of testimonials, even the more hesitant, less risk taking faculty members indicated changes in their teaching. One of the participants stated, "I am a lecturer and I have learned to break up my lectures." Another discussed providing more structure to lectures by providing students with an outline of the lecture and overview at the end of the lecture. One of the faculty, who had tried her first group project and used a rubric to communicate expectations to students, summarized the challenge of teaching by sharing her success with using a new strategy with her students, but her frustration because "grades are still low."

### **Conclusion**

The seminar provided a successful format for faculty members to expand their knowledge of teaching and learning and to receive support as they tried new strategies. From participating in the seminar, all ten faculty members and seminar leader built collegial relationships with faculty members in different departments. The seminar raised the level of awareness among the faculty of the research base and reform movements in education. Reflecting on teaching and doing research on your own practice is a slow process and one that is new to most faculty members.

By knowing about teaching and learning research and applying it in their classes, the faculty will be better able to provide instruction to meet the diverse needs of their students. This will also likely provide future teachers with increased knowledge of science and mathematics and therefore, assist them in providing appropriate learning experiences for children.

Since the university sponsored the seminar, it sends a clear message that teaching is valued as well as research. The second year of the seminar is now in progress. ■



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# **A PRELIMINARY ANALYSIS OF THE SUPPLY AND DEMAND FOR MIDDLE SCHOOL MATHEMATICS AND SCIENCE TEACHERS IN VIRGINIA**

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Virginia Colleges and Universities have a major challenge to produce educated elementary and middle school students. The magnitude of this challenge can be measured by studying the number of current teachers in each grade in Virginia and the anticipated retirements and departures from the profession for other reasons. The new licensure requirements have their biggest impact for the preparation of middle school teachers since middle school teachers will no longer be able to receive general middle school certification.

During its organizational meeting, the conference steering committee agreed that some analysis of data upon which to base projections of teacher supply and demand would be useful. The official charge was to examine the number of teachers in the Commonwealth and to project the number of elementary and middle-school science teachers required for the next several years, in light of the new certification requirements.

One might assume that someone in Richmond would have the necessary data and that the project would simply entail tracking it down. That assumption is patently incorrect! First of all, there is very little current data on Virginia. The most recent published data on things as simple as the number of teachers in the Commonwealth is found in the 1996-97 *Superintendent's Annual Report* [1]. Various calls to persons in the Department of Education yielded no comprehensive information. The Virginia Education Association (VEA) had lots of information, but little that was useful for this analysis. Regional and national sources of data, such as the Southern Regional Education Board (SREB), the National Center for Educational Statistics (NCES), and the Eisenhower National Clearinghouse (ENC) were examined. The SREB provided a 1994 report entitled *Educator Supply and Demand in Virginia* [2], which although dated, was useful. The NCES provided some national projections of teacher demand, while the ENC provided some ten-year old data which is marginally useful. Local school systems seem to know least of all what their long-term needs will be. Obviously they have information on the age distribution of teachers and can to some

extent project retirements, but they have little means other than the past for forecasting teacher retention, etc.

Given the paucity of data, where do we begin? First of all, on a national basis, is there an impending shortage of teachers or not? Sources ranging from the US Department of Education [3] to the Wall Street Journal claim a need for as many as two million new teachers in the next decade. Such estimates are based on the aging teacher workforce nationwide as shown in Figure 1, contrasted with projected increases in student enrollment. The National Council of Teachers of Mathematics (NCTM) raises strong concerns about the possible shortage of mathematics teachers [4]. But the Wall Street Journal [5] also reports that the pending shortage is simply another effort by the supporters of education to divert money into education. The shortage is not real because there are millions of teachers in the country who have left teaching but will return and millions of others desperate to teach but unable to do so because of arbitrary and strangling certification requirements.

We will begin this analysis by looking at projections of the numbers of teachers needed provided by the National Center for Education Statistics [6]. Updated in July of 1998, these projections show growth in the number of teachers based upon a commonly accepted statistical model. Figure 2 indicates a projected growth between 1994 and 1998 of approximately 500,000 new teaching positions nationwide. Figure 3 indicates an annual growth rate of 1.3% between 1996-2002 and a smaller growth rate of about 0.9% during the next six years. Figure 4 shows that most of the projected growth occurs in the K-8 grade levels, while high school growth is relatively flat. Figure 5 indicates how the enrollment is expected to change, state by state, during the same period. Notice that Virginia shows a growth in enrollment which is less than seven per cent. Figure 6 indicates one more important factor influencing the number of teachers employed--the student teacher ratio. This ratio has been declining steadily and is projected to continue to decline at the elementary level. Finally, some data reported by the Central Michigan University (Figure 7) indicates projected shortages of teachers by region across the south.

Certification of elementary and middle-school mathematics and science teachers drove the creation of this conference and brought each participant to the conference. Data on certification is more difficult to find. The Eisenhower National Clearinghouse [7] has

published some national (1994) data on certification for middle school math and science teachers. Their data indicates that in states which have had such certification, of the teachers teaching science in grades 7 and 8, 53% were certified in science. Forty five percent of those teaching math were certified. The NCTM estimates that 34% of secondary teachers are teaching mathematics with neither a major nor a minor in the subject. Figure 8 summarizes some preliminary data from a study commissioned by the Virginia Mathematics and Science Coalition [8]. Responses from 280 middle-school mathematics teachers indicate that about 25% have six or fewer hours of college-level mathematics; about 61% have 15 or fewer hours and fewer than 40% have enough hours to complete a major or minor in mathematics.

Several factors affect projections of math/science teacher supply and demand. First, early retirement incentives--state and local--can substantially alter the demand. What many teachers perceive to be a deteriorating classroom environment requiring more and more attention to fewer and fewer students affects the longevity of classroom teachers. The Standards of Learning and subsequent teacher accountability will have a substantial effect, at this point completely unknown. Beginning teacher salaries do not compete with salaries associated with other careers available to technically qualified graduates. The use of non-certified teachers, particularly if certification requirements are circumvented to allow persons such as retired military to teach without certification, can change the supply of teachers. The implications of strengthened certification requirements in mathematics and science for those desiring to return to teaching after some absence is also an unknown factor.

The SREB report projects teacher needs for the Commonwealth between 1994 and 1998. While much of the study is not germane to our interests, some data is interesting. Figure 9 shows a breakdown by race for Virginia high-school teachers in 1992. At that point 13% of all high school teachers were Black. There were 27 Black physics teachers and 38 Black chemistry teachers statewide in 1992. Figure 10 shows the age distribution of Virginia teachers in 1992, following the statewide early retirement incentive offered in 1991. Notice that it does not show the strong peak at age 50 as found in national data (Figure 1). Figure 11 summarizes the report's projections for teacher supply and demand through 1997. The SREB projected shortages or surpluses in terms of classes, not teachers. So if one assumes five classes per teacher, then a surplus of 20 equates to four teachers. This makes some sense if the classes are concentrated in four or five-class bunches by schools. Otherwise a shortage

of 20 classes statewide might imply a shortage of 20 qualified teachers in 20 different schools. The report concluded that all of the projected shortages were negligible.

Now to rough projections for the need for science and math teachers in the Commonwealth. Physicists would call this is an "order of magnitude calculation." First, according to the 1996-7 *Superintendent's Annual Report*, Virginia has about 48,805 K-7 teachers. If we assume (incorrectly) an even distribution among the eight grades, we calculate that about 12,000 of these are teaching grades 6-7, while the remaining 36,000 are teaching K-5. Using the same assumptions, approximately 6000 of the 31,100 secondary teachers teach eighth grade. So the Commonwealth has approximately 12,000 middle school teachers (7-8) and about 42,000 K-6 teachers. (These data are accurate for 96-97-- current numbers are slightly higher.)

In Lynchburg City Schools and surrounding school districts, approximately 10% of the middle school teaching staff teach mathematics and a like percentage teach science. Applying these percentages statewide leads to the following conclusion: Approximately 1200 persons teach middle school (7-8) mathematics and a like number teach middle school (7-8) science. Another 1200 teach presumably teach sixth-grade mathematics and science.

If we assume (again incorrectly) no attrition and that all currently assigned middle school math/science teachers are certified and teaching in their fields, then growth rates of 15%, as projected nationally by NCES, would require 180 additional middle school math teachers by 2007. Such growth would require 25 additional middle school math teachers per year. Similar numbers apply for middle school science teachers. The same reasoning leads to an estimate of 6300 additional K-5 teachers by 2007, about 900 per year, who meet the new certification requirements in mathematics and science. If we assume that teacher growth parallels student population growth, then seven per cent would be more reasonable. This leads to a much smaller number -- 84 new middle school math teachers by 2007, about 12 per year. Similar numbers apply for science and K-5 teachers.

The SREB report indicates an average attrition for Virginia teachers of about 7% per year. If we assume 7% attrition, then an additional 84 trained middle school mathematics teachers and an additional 84 trained middle science teachers will be needed each year.

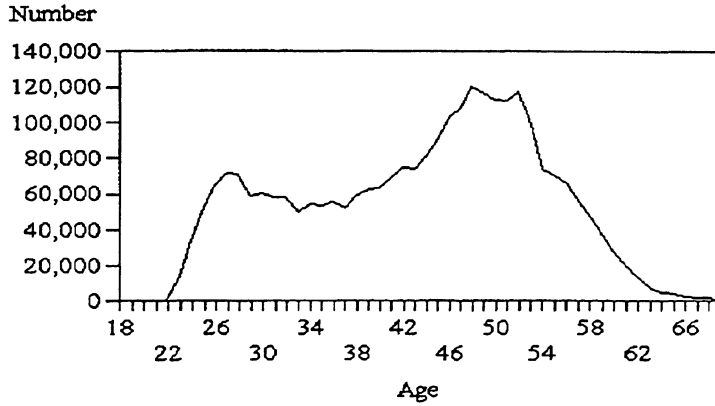
Persons in the non-working trained teacher pool will not meet the new certification requirements, although they may have maintained certification. So a conservative estimate leads to numbers from slightly less than 100 to about 115 newly trained 7-8 math teachers each year and a like number of 7-8 science teachers.

An informal telephone poll of schools and departments of education in the Commonwealth, as well as a study of catalog information leads to a conservative (on the high side) estimate that the current statewide production of math-science middle school (7-8) teachers is between ten and twenty total. The number may be much smaller.

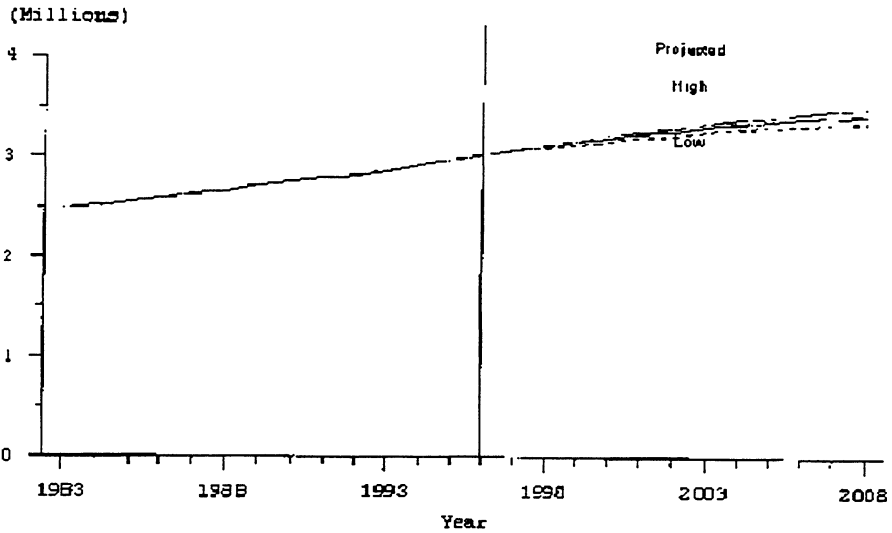
Given the current situation, even the most modest projected increase presents a real challenge. How do we encourage the "best and brightest" of our mathematics and science students to pass up the monetary rewards of research or college teaching or management to pursue careers teaching our young people? Or how do we encourage those in the next tier, who have the ability but perhaps not the confidence, to pursue mathematics or science education? Perhaps the answers to those questions will provide the substance of a future conference. ■

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**Figure 1. Estimated age distribution of full-time equivalent public school teachers: 1998-99.**



**Figure 2. Elementary and Secondary classroom teachers, with alternative projections: Fall 1983 to Fall 2008.**

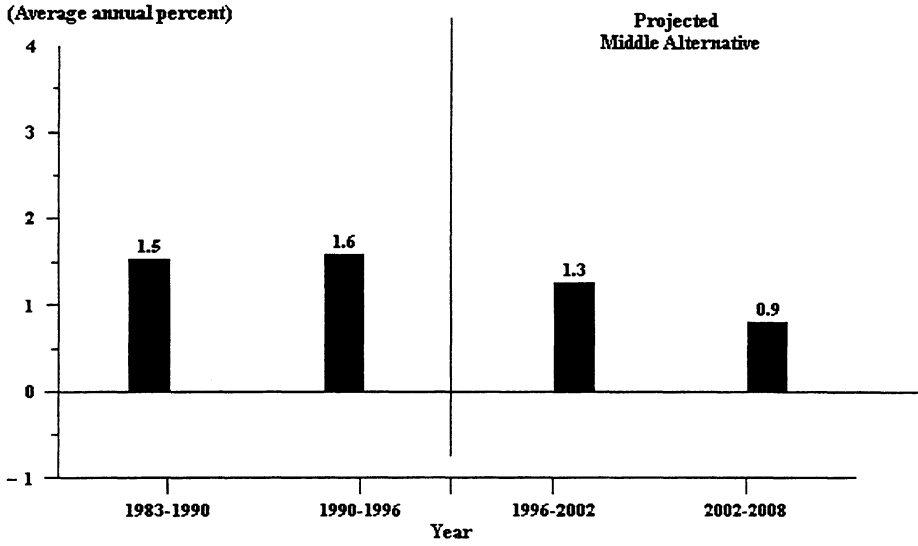


Figure 3. Average annual growth rates for classroom teachers.

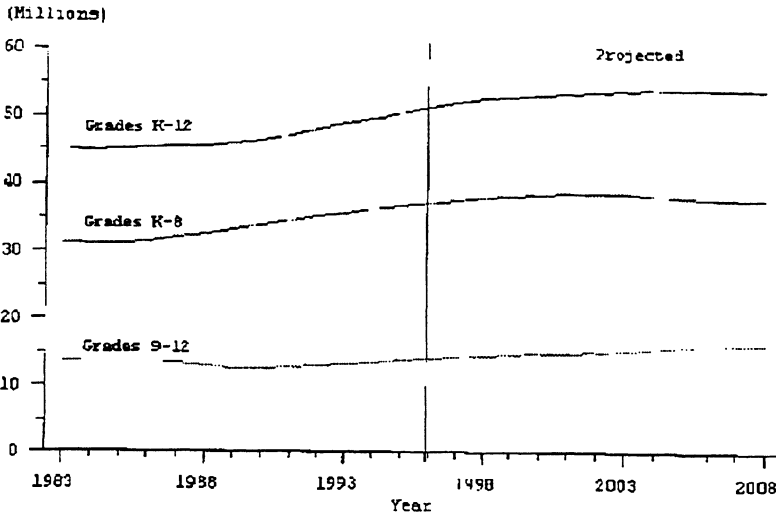
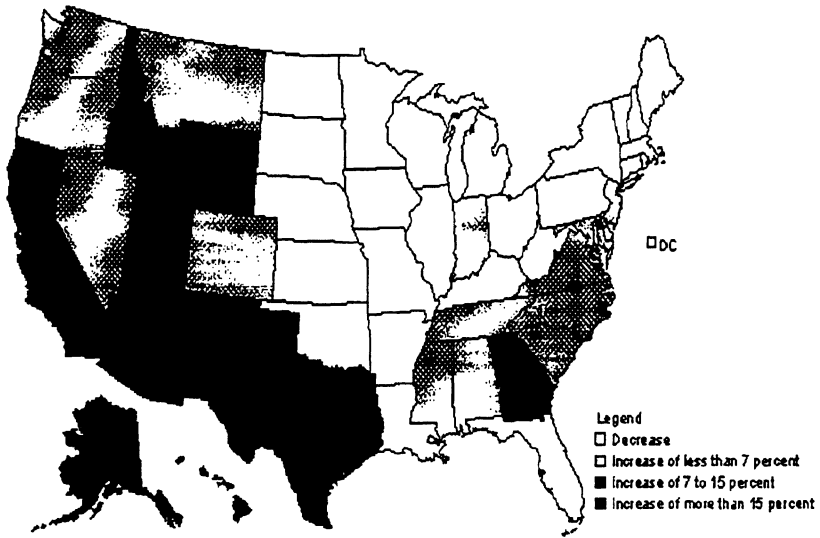
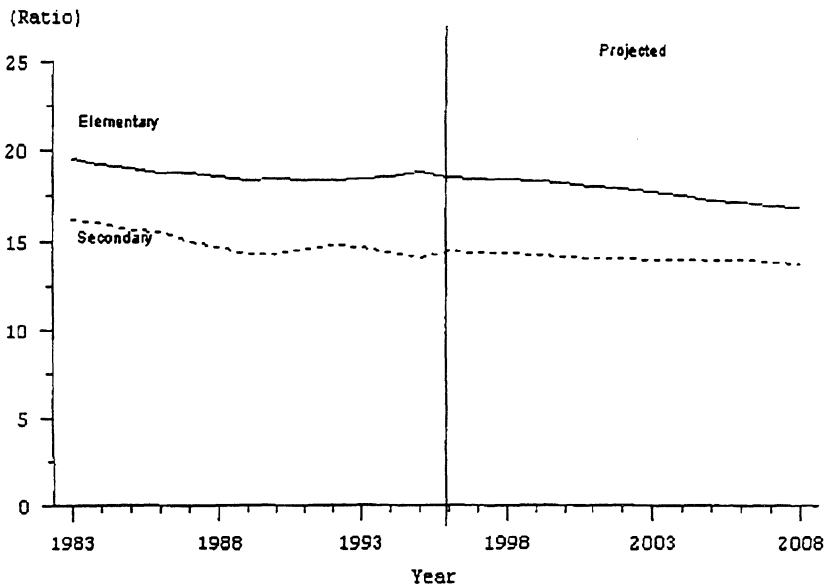


Figure 4. Enrollment in elementary and secondary schools, by grade level, with projections: Fall 1983 to Fall 2008.





**Figure 5. Percent change in grades K-8 enrollment in public schools, by state: Fall 1996 to Fall 2008.**



**Figure 6. Pupil-teacher ratios, by organizational level, with middle alternative projections: Fall 1983 to Fall 2008.**

	South Central	Southeast	Middle Atlantic
Biology	3.77	3.68	3.27
Chemistry	4.07	3.96	3.62
Computer Science	3.73	3.83	3.42
Earth Science	3.78	3.57	3.42
General	3.70	3.62	3.20
Mathematics	4.24	4.87	3.50
Physics	4.08	3.96	4.00

Key: >4.20=considerable shortage, >3.40=some shortage, >2.60= balanced, >1.80= some surplus

**Figure 7. Relative Demand for Science-Mathematics Teachers** (1995 data from Central Michigan University).

Subject taught	Majored in subject matter taught	Minored in subject matter taught	Teaching out-of-field of initial preparation (did not initially minor or major in discipline currently taught)
Science	31% (Major in science or science education)	13% (Minor in science or science education)	56%
Mathematics	20% (Major in math or math education)	13% (Minor in math or math education)	67%

**Figure 8. Initial Preparation of Current Middle School Teachers** (Virginia Mathematics and Science Coalition White Paper, May 1999).

Subject Area	Black	All	Percent Black
All High School	3060	22781	13
Foreign Language	107*	1916	6
Physics	27	384	7
Chemistry	38	549	7
Earth Science	92	815	11
Mathematics	397	3349	12
Biology	115	973	12
Social Studies	334	2899	12
English/Language Arts	489	4234	12
Other Science	42	282	15
Physical Science	150	815	18
Health Physical Education	458	2599	18
Special Education	1515	8223	18
Principal Elementary and Middle	450	2156	21
Principal Other and Secondary	211	1075	20
*These are persons who teach at least one class in the listed subject.			

**Figure 9. Race/Ethnicity and High School Teaching, Virginia 1992** (Report from Southern Regional Educational Board).

		Age in Years					
Year	Race		20-29	30-39	40-49	50	Total*
1988	All	Number	9,961	25,517	21,990	12,256	70,581
		%	14	36	31	17	100
1992	All	Number	10,741	21,707	30,152	12,332	76,296
		%	14	28	40	16	100
1992	White	Number	9,740	25,343	25,188	9,791	63,523
		%	15	28	40	14	100
1992	Black	Number	833	3,798	4,675	2,422	11,914
		%	7	32	39	20	100
*Does not total exactly because there are missing cases for age category in every year.							

**Figure 10. Age of Virginia Educator Workforce by Race 1988 and 1992 (Report from Southern Regional Educational Board).**

Assignment Area	Year	Projected Number of Classes Needed	Projected Surplus or Shortage of Classes
<b>Early Childhood</b>			
Pre-K and K	1995	4,726	4
Grades 1-3	1997	12,041	
Grades 4-7	1998	12,721	6
<b>Elementary and Middle</b>			
Science	1997	4,215	0
Social Studies	2000	4,111	2
<b>High School</b>			
Foreign Language	1996	8,872	-21
	1997	9,031	7
English Language Arts	1996	19,245	-48
	1997	19,881	17
Mathematics	1996	14,538	-36
	1997	15,018	13
Physics	1996	992	-2
	1997	1,010	
Chemistry	1996	2,084	-5
	1997	2,122	2
Social Studies	1996	13,109	-33
	1997	13,542	11

**Figure 11. Projected Supply and Demand for Educators in Virginia** (Report from Southern Regional Educational Board).

## **COMMUNITY COLLEGE PERSPECTIVES ON TEACHER PREPARATION IN VIRGINIA**

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The need for future teachers who are well versed in mathematics and science will not be provided by Virginia's four-year institutions alone. A large portion of those students who complete their K-8 teacher preparation programs at Virginia's four-year institutions have studied a significant portion, if not all, of their mathematics and science at community colleges. Therefore, if future teachers are to have completed appropriate mathematics and science courses these must be provided by the community colleges. In addition, community colleges can play a critical role in attracting people with a high potential for becoming excellent teachers. Two-year colleges are located in urban and rural areas, enroll a large portion of Virginia's minority students, and welcome returning adults. We need to attract students from this source if we are to produce sufficient numbers of well prepared teachers in Virginia. A recent National Science Foundation workshop developed detailed recommendations concerning the role of two-year colleges. This paper will focus on these recommendations.

Nationwide, community colleges have significant enrollments, tremendous diversity, and experienced faculty who are committed to teaching excellence. Community colleges are well positioned to provide leadership in teacher preparation and must work with four-year schools to recruit and train the best and brightest students into the teaching profession.

### **Historic Perspective**

The oldest two-year college in the United States was founded in 1901 in Chicago, by William Rainey Harper, President of the University of Chicago. In 1947, the Truman Commission Report defined the term "community college" and the mission of the two-year school. The community college would charge little or no tuition, serve as a cultural center, be comprehensive in offerings, and serve the area in which it was located [1]. In other words, the community college would provide area citizens with an excellent, well rounded, low-cost education. Throughout the nation, community colleges have successfully provided these same services for ninety-eight years.

### **National Need**

In *President Clinton's Call to Action for American Education in the 21<sup>st</sup> Century, Talented Teachers in Every Classroom*, the President states that in the next ten years we will need to hire two million new public school teachers due to massive retirements and growing student enrollments [2]. A teacher shortage already exists within the minority ranks. Minority faculty represent fourteen percent of the K-12 teaching faculty nationwide, while more than thirty-two percent of the students in the K-12 system are minority [3]. In addition to the growing teacher shortage, the quality of science and mathematics textbooks, and teaching quality in United States public school systems, compound the problem as presented in *A Splintered Vision: An Investigation of U. S. Science and Mathematics Education*, from the Third International Mathematics and Science Study (TIMSS) [4]. This report warned that mathematics and science curricula, textbooks, and teaching in the United States are *a mile wide and an inch deep*. In 1998, the poor test results of our high school seniors on TIMSS testing, compared to other countries, was reported [5]. The teacher shortage data considered along with the warning from *A Splintered Vision*, and the poor performance of our high school seniors on TIMSS tests strongly suggests that the United States public school system is in crisis.

### **Community College Resources**

The American Association of Community colleges reports that 1,123 colleges enroll 45% of all United States undergraduates. Their student profiles reveal that 42% of all African Americans, 55% percent of all Hispanic Americans, 40% of all Asian/Pacific Islanders and 50% of all Native Americans in higher education are enrolled at community colleges [6]. Community colleges, strategically located throughout the country, with their large, diverse student body and a faculty committed to teaching, must join with four-year schools to recruit and produce the teachers that will enter classrooms in the United States in the next ten years.

### **National Conference**

The tremendous resources of our nation's community colleges have been highly underutilized in the area of teacher preparation. In an effort to highlight the ongoing, successful role of community colleges in teacher preparation, the Division of Undergraduate Education of the National Science Foundation (NSF) sponsored the national conference, *The Integral Role of the Two-Year College in the Science and Mathematics Preparation of Prospective*

*Teachers*. Eleven community colleges with exemplary activities in science and mathematics for prospective teachers, were selected through a national competition, to be showcased and studied during the conference. Community colleges selected as having exemplary activities included: Austin Community College, Borough of Manhattan Community College, College of San Mateo, Community College of Philadelphia, Delaware Technical and Community College, Grand Rapids Community College, Green River Community College, Henry Ford Community College, J. Sargeant Reynolds Community College, Tulsa Community College and William Rainey Harper Community College. Detailed descriptions of these exemplary programs were published in a special issue of *The Journal of Mathematics and Science: Collaborative Explorations* [7].

More than one hundred individuals including science and mathematics faculty, college presidents and other administrators, as well as national leaders in science and mathematics professional societies participated in this conference.

### **National Recommendations**

Participants worked at this conference to better understand the role of the community college in teacher preparation and to formulate national recommendations on how to best utilize the resources of the community college to produce teachers well prepared to teach science, mathematics, engineering, and technology. The areas of teacher preparation included in the formulation of the recommendations were:

- 1) recruitment of prospective teachers
  - 2) strengthening undergraduate science, mathematics, engineering, and technology courses
  - 3) pre-teaching experiences
  - 4) in-service activities
  - 5) liaisons between two-year colleges and four-year institutions
  - 6) connections with business and industry, professional societies, and other organizations.
- These recommendations were published as a report from the National Science Foundation Workshop, *Investing in Tomorrow's Teachers: The Integral Role of Two-Year Colleges in the Science and Mathematics Preparation of Prospective Teachers* [7].

### **Call to Action**

This report calls upon community colleges to use their large and diverse student bodies



for the active recruitment of prospective teachers from their service areas, providing classroom teachers who will best understand the needs of these communities [8]. Two-year college faculty are called upon to use their expertise in providing quality instruction in introductory freshman and sophomore courses and to demonstrate leadership in strengthening science, mathematics, engineering, and technology courses taken by prospective teachers at the community college. Community colleges must provide the prospective teacher with pre-teaching experiences. An introduction to early, rich, and varied pre-teaching experiences in science, mathematics, engineering, and technology at the community college will reinforce both an interest in and commitment to excellence in teaching. Two-year colleges are encouraged to provide current teachers with in-service training in science, mathematics, engineering, and technology courses. The two-year college working with local school systems may serve as the primary provider of in-service programs in rural areas [8].

It was recognized at this conference that the role of the community college in teacher preparation must be carefully coordinated with four-year institutions, particularly in light of articulation agreements and transfer policies. In order to provide mutual support for the prospective teacher at both institutions, the two-year and four-year schools must work together to align and strengthen science, mathematics, engineering, and technology courses. Additionally, liaisons between two-year schools, business and industry, professional societies, state legislatures, statewide and national policy boards, and four-year institutions will allow two-year colleges to become full partners in the science, mathematics, engineering, and technology preparation of future teachers [8].

I am pleased to report that in Virginia, community colleges are beginning to take their role in the preparation of teachers very seriously. For example, J. Sargeant Reynolds Community College is working very closely with Virginia Commonwealth University to recruit and prepare future teachers. The Chancellor of the Virginia Community College System (VCCS), Dr. Arnold Oliver, is forming a statewide community college task force to study the issues of teacher preparation. This task force will recommend how the resources of Virginia's twenty-three community colleges can best be utilized to help prepare highly qualified K-12 teachers. The VCCS, as well as professional organizations in the state of Virginia are committed to taking steps to raise the level of awareness to the importance of teacher preparation. ■

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## **CREATING THE NEED TO KNOW**

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Context-based teaching provides a strategy that gives the responsibility of learning back to the student. This approach is being used at Virginia Tech in a number of settings, including an introductory Biology class with 325 students.

Remember when you were a student listening to another lecture that followed the sequential format of the textbook? I venture that it was not only boring, but you were probably wondering why you needed to learn facts that had no immediate relevance. Were you engaged in learning? Probably not! As an instructor, are you constrained by standards of learning? Do you feel that you need to teach everything in the text, but you do not have enough time? Has it gotten to the point where you do not enjoy going to class? Why don't you change your teaching strategy?

There is a strategy that gives the responsibility of learning the material back to the student instead of having to teach it all. And it is fun. It is called context-based teaching. You may know it as case-study approach, or as thematic or situation-based learning. Case studies are usually presented as questions at the end of each chapter or as a supplement to a textbook. What makes this model of teaching different is that the facts are learned in context, as needed and with relevance.

I have experimented with context-based teaching in three of my college classes. The first was an introductory Biology course with 325 students where the students are presented with questions that required critical thinking, collection and integration of seemingly disjunct facts. In a 75-minute class session, the students only received a 20-minute mini-lecture based on a concept map. The rest of the time was in discussion of possible solutions to the problem of the day.

The second was a six-week on-line general Biology course that followed a traditional text, but in part it also incorporated Aldous Huxley's *Ape and Essence*. An open-book question required the integration of diverse facts and concepts found throughout the textbook. Each

student was asked to determine if the purification rites of Belial would be effective in reducing the number of radiation-induced mutations in a human population. The student was also asked to propose a screening test for people who did not phenotypically express mutations so society could decide if they could breed or not. If mutations were identified, the student had to discuss the techniques they would use to repair these defects. They also had to estimate how many generations and years would be necessary before they knew whether this selective breeding program was a success or not.

The third course was a sophomore-level, three credit Ecology class that met four hours per day, five days a week, for three weeks. There were no lectures. Instead, I asked the students bring the Serengeti to Virginia. The ecosystem had to have a minimum of 25 species integrated into a viable food web. The system had to survive at least three times the life expectancy of the top carnivores, and students had to prove it by constructing a Serengeti food chain using Stella, a software package. In addition, if they modified the Virginia environment, they had to justify the modifications. Finally, they had to identify which biogeochemical cycle they would use to indicate ecosystem health. Not only did these students efficiently cover the material in the textbook, but they were also researching material typically presented in graduate level courses.

Currently, I am designing a course that will be totally context-based. There will be little or no lecture. I propose teaching a two-semester General Biology course by asking the students only three or four meta-level (first order) questions that will ultimately cover most of the material in the text. Students literally create their own learning environment as they brainstorm answers to their own questions. In turn, each question generates more questions and the need to learn new material. When the students have answered all the possible questions, they will have covered most of the material in the textbook. Factual material is learned as needed rather than being presented as a linear sequence of facts.

The first three meta-questions they will be asked in this new course are: 1) Cheetahs - an endangered species: can and should they be saved?, 2) Water, why should we care?, and 3) Biotechnology, is it a panacea? As an example, the question "Cheetahs - an endangered species: can and should they be saved?", should generate several new second-order questions. There are at least five second-order questions that could be asked: 1) What is a species?, 2)

What is an endangered species?, 3) Why are species becoming extinct?, 4) Why is the cheetah of interest to ecologists ?, and 5) Why are taxonomists interested in cheetahs? Each of these questions should generate new questions. There are no limits to the number and diversity of questions that can be asked. In this module being developed there are approximately six levels of questions. Once a student has researched each meta-question, he or she will need to pass a quiz to demonstrate that they have sufficient knowledge about the subject before they make a decision about the future of the cheetah.

Context-based learning does not need to stop with biology. Context-based learning can integrate biology, sociology, ethics, politics, etc. As it turns out, cheetahs have virtually no genetic diversity. So a student may decide that they do not want to save the cheetah. If a student decides not to save the cat, then he or she will need to learn why countries have signed an international agreement to preserve biodiversity. If a student feels we should save the cheetah, they need to decide how much they are willing to pay for this effort. If cost is not an issue, then the student will need to identify which social programs may need to be dropped or how much taxes should be increased to pay for this effort. If the student changes their mind at this point, they again must address the issue of conservation of biodiversity. However, if they still want to save the cheetah, then the next question is how will they increase cheetah genetic diversity? Now we come full circle. Students now will have to understand biotechnology and decide which techniques can be used to increase the genetic diversity of cheetahs. When I presented a class with the problem of increasing genetic diversity of cheetahs using biotechnology, they proposed 13 different solutions to the problem. The diverse answers included the use of drug therapy to make the animals better mothers, selective breeding programs, repairing cheetah genes by using genes from lions or other cats, using genes from cheetah museum skins and mummified cats from Egypt, and controlling the predators of the cubs.

Context-based learning also allows for multiple ways to enter a module. The five second-order questions noted above offers the student a choice of where to begin to answer the meta-question. Students who have a choice of which question to answer first are apt to be more motivated to learn. To gather the appropriate information to answer the meta-question, a conscientious student will at least have to answer all the questions posited. A student could also enter the module by asking a very specific question. For example, when studying viruses

and bacteria, a question could be asked about the impact of diseases on the population dynamics of wild animals such as cheetahs.

The initial response to the use of meta-questions in teaching has been received with enthusiasm by the students. It is not uncommon to hear the student make comments such as these: "Thank you for not covering the same material that is in the text," "This was fun," and "Now I understand why I have to take Biology." And so forth. From the instructor's perspective, I enjoy teaching much more than I did as a lecturer. This does not mean that context-based teaching is easier than lecturing. It is not easier because I do not know exactly what will happen in class each day, nor will I know all the answers to other questions a student might ask. However, it is not important that I know everything, but it is important that I serve as a role model of how we all use scientific thinking in our daily life, solving problems and answering questions. ■

# **SCIENTISTS AND SCIENCE EDUCATORS: COLLABORATING TO DEVELOP CONCEPTUAL CHANGE TEACHING STRATEGIES**

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Research in science education has identified conceptual change teaching strategies that may enhance pre-service teachers' understanding of scientific concepts and processes. These strategies, supported by constructivist learning theory in the social and cognitive sciences, include the use of discrepant events to engage students' prior knowledge, the learning cycle, and collaborative learning. Science educators have used these strategies to challenge alternative conceptions of pre-service K-8 teachers in methods courses in an effort to facilitate learning scientific concepts. Pre-service K-8 teachers, motivated to explore scientific phenomena and clarify their own understandings, gain confidence in their ability to learn science and are better prepared to use similar strategies with children. In redesigning innovative courses for pre-service teachers in university science departments, scientists and science educators would benefit from a mutual collaboration to develop instructional strategies informed by constructivist learning theory. In this partnership, scientists, experts in content and scientific research, would work with science educators to develop curriculum in both science and science methods courses that challenges pre-service teachers' existing knowledge and facilitates more authentic understandings of science. A more seamless transition would thus be possible between science courses and science methods courses.

Research in science education has identified teaching strategies that use a conceptual change approach to enhance pre-service teachers' understanding of scientific concepts and processes [1, 2, 3]. These strategies, supported by constructivist learning theory in the social and cognitive sciences, are designed to challenge students' existing conceptions of scientific phenomena while helping students develop more acceptable scientific understandings. In this paper, we will discuss various teaching strategies designed to promote conceptual change, including discrepant events, the learning cycle, and collaborative learning. We will also suggest that scientists and science educators collaborate as they develop innovative science and science methods courses that promote conceptual change teaching and learning.

## **CONCEPTUAL CHANGE TEACHING**

Inquiry teaching strategies, recommended in science education reform documents, involve students in active learning, examination of evidence, and interpretation of scientific phe-



nomena [4]. Students' learning and understanding of science, however, is influenced by the prior knowledge that they bring to science classes:

The concepts of the world that students bring to school will shape the way they engage in science investigations, and serve as filters for their explanations of scientific phenomena [5].

According to research into how children learn, students come to science classes with common sense ideas or alternative conceptions about scientific phenomena [6]. For example, in a study of ninth graders [7], it was found that most of them believed that there is no gravity on the moon as only 28.9 % of the students thought a wrench (dropped by an astronaut) would fall toward the moon's surface. Further, teachers were not aware of students' alternative conceptions of gravity, as 73.5 % of the teachers predicted that students would choose the scientifically acceptable response. Similar research has documented students' alternative science conceptions on numerous science topics in grades K-12 and college, including mechanics, electricity, heat, optics, particulate nature of matter, energy, conceptions of life, genetics, and evolution [8]. These alternative conceptions of students are known to influence learning and are very resistant to change.

The job of the science teacher is to help students connect their prior knowledge with current understandings of scientific phenomena. Often this requires students to change their existing viewpoints and conceptions to accommodate more scientifically acceptable explanations. This task is difficult because many teachers, particularly those learning to teach in elementary schools, do not have an extensive science background. According to Wandersee [8], elementary teachers often have the same alternative science conceptions as their students.

Discrepant Events. In response to helping students experience meaningful learning and develop their scientific understandings, innovative approaches have been developed to challenge students' prior knowledge. Based on Piagetian learning theory, discrepant events (investigations of scientific phenomena with surprising or unexpected results) are used to challenge students' existing conceptions by promoting cognitive disequilibrium [9]. For example, students may investigate the refraction of light by placing a coin under a beaker and then pouring water into a beaker. Confronted with surprising results (the image of the coin

from the side of the beaker apparently disappears from view), students are motivated to find the reason for this discrepant observation. Similarly, in the history of science, anomalies have traditionally spurred new scientific understandings and theoretical thought [10]. According to Piaget, when students' prior knowledge is challenged, students will reorganize or accommodate their existing prior knowledge by making new connections with observed phenomena.

Learning Cycle. Another instructional strategy designed to promote conceptual change is the three-phase learning cycle instructional sequence [11, 12]. Unlike the traditional lecture-lab format, the first phase of the learning cycle engages students in exploration and inquiry investigations before presenting scientific information. Student explorations through discrepant events, dialogue, or other investigations encourage students to access their prior knowledge and in the process, they become motivated to learn and find out more information.

During the second phase of the learning cycle, teachers may introduce concepts or assign reading and research to help students clarify their understandings. During this time, traditional lectures may be more appropriate because students would be motivated to learn more about scientific information and explanations related to their explorations. Students could further clarify their understandings and establish connections with existing knowledge by creating conceptual or schematic maps of their ideas [13]. The third phase involves students in further investigative activity as they apply or elaborate on their existing knowledge. In the process of teaching through the learning cycle, students have opportunities to change their existing understandings of science.

Collaborative Learning. Inquiry and conceptual change teaching is also enhanced by involving students in collaborative learning. During collaborative learning, student thinking is stimulated when students share ideas and discuss strategies for investigating scientific phenomena. According to Lev Vygotsky, teachers should create an environment which challenges students to learn more in a group than they could learn individually [14]. Just as scientists collaborate in their research, scientists and science educators should be promoting collaboration and dialogue among pre-service teachers. Pre-service teachers, motivated to explore scientific phenomena and clarify their own understandings with their peers, gain confidence in their ability to learn science and are better prepared to use similar strategies with

children.

## COLLABORATION: SCIENTISTS AND SCIENCE EDUCATORS

In many undergraduate science courses that pre-service teachers enroll, students' prior knowledge about science is not challenged by traditional lecture teaching methods in which students take notes and memorize information to pass a test. In fact, students may compartmentalize their own prior knowledge and answer test questions correctly without meaningfully connecting their existing knowledge to scientific knowledge [8].

In redesigning innovative courses for pre-service teachers in university science departments, scientists and science educators would benefit from a mutual collaboration to develop instructional strategies informed by constructivist learning theory and research on students' alternative science conceptions. In this partnership, scientists, experts in content and scientific research, would work with science educators to redesign introductory science courses and laboratory activities to be more inquiry-based and discrepant in nature. Teams of science and science education professors would collaborate to develop conceptual change teaching strategies that challenge pre-service teachers' existing knowledge. Science professors, for example, could experiment with innovative strategies such as the learning cycle to break from the traditional lecture-lab format.

Investigative non-traditional laboratory activities have been successful in engaging students in problem solving in undergraduate biology classes [15]. In this study, students departed from "cookbook" laboratory exercises and designed their own experiments to investigate the respiration of yeast. Students formulated their own hypothesis and tested their ideas to investigate the alcohol content of naturally aged wine. This pilot project was the result of collaboration between science professors and science educators.

Alternately, science educators would benefit from collaboration with scientists to redesign the science methods curriculum. Science professors would be invaluable as a resource for discussing current scientific research and explanations of discrepant events or other investigations that take place in the methods classes. Scientists would suggest contemporary research methodologies that may enhance inquiry activities of pre-service teachers. Collaboration between science and science methods professors would promote a more

seamless transition between science content courses and methods courses for pre-service K-8 teachers. Learning from scientists and science educators as role models, pre-service K-8 teachers would be better prepared to engage children in conceptual change teaching and learning. ■

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# **A FIELD BASED APPROACH TO INTRODUCTORY GEOLOGY INSTRUCTION**

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As part of the NSF-funded VCEPT project, geology faculty at Mary Washington College have developed and pilot tested a two-semester sequence of geology courses which are taught in a non-traditional, discovery oriented style. The guiding philosophy of the course development is to ensure that students learn about geological principles through collaborative learning in a variety of field settings that were carefully chosen to provide good examples of a range of geologic processes and environments. The design goals of these courses include improvement in student retention of concepts, increased student interest in earth science, improved critical thinking skills and the promotion of collaborative learning. Development of the courses required multiple visits by geology faculty to numerous field sites in order to determine the suitability of using each site to teach fundamentals such as mineralogy, formation of igneous, sedimentary, and metamorphic rocks and deformation features. Students are provided with field notebooks, local topographic maps and basic field tools such as Brunton compasses and hand lenses. Each student maintains his or her own field notebook in order to record increasingly sophisticated observations regarding geologic features within eastern Virginia. Eventually, teams of students present and defend an overall chronology of geologic events for the mid-Atlantic Appalachian region. Course assessment tools include written student comment sheets, standardized course reaction questionnaire scores and tracking of students who decide to continue within the geology major.

In recent years faculty members in the Department of Environmental Science and Geology at Mary Washington College have been engaged in a thorough revision of the introductory, two-semester geology course sequence. The course development work has been carried out with the support of the NSF-funded Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT). The courses which are being revised are GEOL 111: Introduction to Geology and GEOL 112: Evolution of the Earth. These courses are provided for prospective majors, pre-service teachers, and general education students alike. Within the Mary Washington College curriculum, as at most institutions, these geology courses have always been offered as traditional lecture classes with a two hour lab each week.

## **Course Development Goals**

Throughout the past several decades demographic changes have altered the composition

of our college student population, and earth science curricula have undergone modifications in order to reflect growing environmental concerns. A review of the literature regarding geologic education, however, reveals that one feature of earth science education has not changed and that is the vital importance of the field experience. Authors of papers from the 1960's [1], 1970's [2], 1980's [3, 4], and 1990's [5, 6, 7, 8] all speak with unanimity regarding the central role that field-based instruction should play within the geology curriculum.

In a typical curriculum, short field trips are used in order for students to see examples of geologic features which have already been studied in class or lab. Faculty involved in course revision at Mary Washington believe that a more ambitious approach should be taken which would allow for students, working in groups, to discover and learn many of the basic principles of geology in the field environment rather than in the classroom. The desired goals of a field-based course design include creating opportunities for active student participation in the discovery and learning process, developing cooperative group dynamics, improving understanding and retention of geologic principles, and exciting a greater interest in pursuing more advanced science classes.

In accordance with this goal, geology faculty members spent several months investigating potential field sites which could be incorporated into the two introductory geology courses. Each field site had to meet several criteria. First, the site must have geological features which are appropriate to the curriculum of either physical or historical geology. Second, each site must be reasonably accessible on public land with suitable parking for vans. Finally, safety considerations of each site must also be taken into account. As a result of these criteria, nine separate field locations were adopted for use. Most of the sites are located within the Fredericksburg area and are situated in public parks.

### **Testing of Pilot Courses**

In order to assess the effectiveness of field-based, discovery oriented instruction, two pilot courses were offered during the 1997 summer session at Mary Washington College. The purpose of offering these courses in the summer term was to permit greater class time flexibility and to ensure a smaller student enrollment in order to test out a variety of field-based teaching strategies. It was also recognized that presentation of course material in a

radically new manner would be a challenge for the faculty and that it might be easier for the faculty members to experiment without the additional distractions of a normal fall or spring semester. At the end of each summer term outcomes assessment material in the form of standardized SIRII questionnaires (see Appendices) were distributed to the students. These are the same forms used in the regular semester classes which provided a comparison of student attitudes toward the heavily revised course curriculum versus the more traditional class offerings. Comment sheets were also provided for anonymous written responses which is also the standard practice during the fall and spring terms. The participating students did not know that the geology classes would be taught in a nontraditional manner at the time of enrollment. A summary of the outcomes assessment data are provided as appendices to this paper.

The design of both introductory geology courses was similar so that continuity was maintained for students who participated in both pilot courses. Daily quizzes were given to improve retention of concepts and ensure that students were keeping up with the material. Each student was provided with a field notebook and topographic map to document his or her observations. At each field site students were provided with an initial briefing in order to make sure that they would remain well focused on the lessons that were intended for that day. This is particularly important in field sites that contain many varied geologic features that can prove distracting. Students then proceeded to record their own observations and reach tentative conclusions about their significance before the course instructor led group discussions regarding the features observed.

During the second term course, students were divided into small groups in which they devised the geologic history of the Fredericksburg, Virginia, region by integrating information obtained from a series of field trips conducted over a period of several weeks. At the end of the process each student wrote a paper justifying the particular geologic history he or she had derived. In addition, each team then made in-class presentations of their conclusions.

As evidenced by the SIRII data, the student responses to the revised courses were extremely positive. The results indicated that the students were more enthusiastic about the material, felt more actively involved in the learning process, and reported improved independent thinking skills. Initial faculty concerns that students would find the unfamiliar



course format confusing appear to be unfounded. Students consistently gave high scores to questions regarding effective use of class time, clarity of exam questions and increased interest in the subject matter. A tangible result of the summer experience was that four students, of the total of sixteen participants, continued as geology majors in the following fall semester. Participating faculty continue to monitor the progress and assess the preparation of these students as they enter upper-level courses and compete with peers who were enrolled in traditional introductory geology classes. ■

## Appendix A

## SIRII – Assessing Courses and Instruction

Comparison of student course reaction questionnaires collected for the pilot Geology 111 course offered in the summer of 1997 and a traditional class taught during the previous fall semester. Both the fall semester class and the pilot course were taught by the same instructor.

Responses: NA (Not Applicable) 5 (Very Effective) 4 (Effective) 3 (Moderately Effective)  
2 (Somewhat Ineffective) 1 (Ineffective)

		100 LEVEL COURSES	GEOL 111 Traditional	GEOL 111 Revised
1.	Instructor's explanation of course requirements	4.24	4.26	4.80
2.	Instructor's preparation for each class	4.38	4.67	5.00
3.	Instructor's command of the subject	4.51	4.65	4.80
4.	Instructor's use of class time	4.22	4.59	4.80
5.	Instructor's way of summarizing points	4.06	4.06	4.90
6.	Instructor's ability to make clear presentations	4.08	4.27	4.80
7.	Instructor's command of English	4.66	4.80	4.90
8.	Instructor's use of examples	4.24	4.43	4.80
9.	Instructor's use of questions	3.98	3.76	4.90
10.	Instructor's enthusiasm for course	4.38	4.27	4.90
11.	Instructor's helpfulness	4.26	4.54	4.90
12.	Instructor's respect for students	4.36	4.75	4.90
13.	Instructor's concern for students	4.11	4.03	4.90
14.	Availability of extra class help	4.15	4.25	4.90
15.	Instructor's willingness to listen	4.39	4.53	4.90
16.	Information about grading policy	4.22	4.40	4.88
17.	Clarity of exam questions	3.92	3.54	4.77
18.	Exam's coverage of important concepts	4.09	3.57	4.88
19.	Quality of instructor's comments	3.82	3.77	5.00

## Appendix A (continued)

		100 LEVEL COURSES	GEOL 111 Traditional	GEOL 111 Revised
20.	Quality of textbook	3.89	3.86	4.55
21.	Helpfulness of work to understand material	3.94	3.59	4.33
22.	Helpfulness of group discussions	**	na	na
23.	Term project	**	na	na
24.	Helpfulness of lab exercises	**	3.98	4.50
25.	Student group projects	**	na	na
26.	Case studies or role playing	**	na	na
27.	Course journals	**	na	na
28.	Instructor's use of computers	**	na	3.90
29.	My learning increased in this course	3.51	3.43	4.11
30.	I made progress achieving objectives	3.44	3.08	4.00
31.	Interest in the subject area increased	3.45	3.28	4.44
32.	Course helped me think independently	3.50	3.14	4.33
33.	Course actively involved me in what I learned	3.58	3.43	5.00
34.	I studied and put effort into this course	3.57	3.66	4.00
35.	I was prepared for each class	3.33	3.29	4.11
36.	I was challenged by this course	3.62	4.08	4.22

NOTE: \*\* Means not reported

## Appendix B

## SIRII – Assessing Courses and Instruction

Comparison of student course reaction questionnaires collected for the pilot Geology 112 course offered in the summer of 1997 and a traditional class taught during the previous fall semester. Both the fall semester class and the pilot course were taught by the same instructor.

Responses: NA (Not Applicable) 5 (Very Effective) 4 (Effective) 3 (Moderately Effective)  
2 (Somewhat Ineffective) 1 (Ineffective)

		100 LEVEL COURSES	GEOL 111 Traditional	GEOL 111 Revised
1.	Instructor's explanation of course requirements	4.24	4.67	4.84
2.	Instructor's preparation for each class	4.38	4.89	5.00
3.	Instructor's command of the subject	4.51	4.78	5.00
4.	Instructor's use of class time	4.22	4.72	4.69
5.	Instructor's way of summarizing points	4.06	4.33	4.61
6.	Instructor's ability to make clear presentations	4.08	4.33	4.92
7.	Instructor's command of English	4.66	4.83	5.00
8.	Instructor's use of examples	4.24	4.39	4.92
9.	Instructor's use of questions	3.98	4.13	4.77
10.	Instructor's enthusiasm for course	4.38	4.39	5.00
11.	Instructor's helpfulness	4.26	4.33	4.92
12.	Instructor's respect for students	4.36	4.28	5.00
13.	Instructor's concern for students	4.11	4.11	4.77
14.	Availability of extra class help	4.15	4.40	5.00
15.	Instructor's willingness to listen	4.39	4.41	4.92
16.	Information about grading policy	4.22	4.39	4.77
17.	Clarity of exam questions	3.92	4.00	4.38
18.	Exam's coverage of important concepts	4.09	4.00	4.46
19.	Quality of instructor's comments	3.82	4.22	4.69

## Appendix B (continued)

		100 LEVEL COURSES	GEOL 111 Traditional	GEOL 111 Revised
20.	Quality of textbook	3.89	3.94	4.69
21.	Helpfulness of work to understand material	3.94	3.64	4.69
22.	Helpfulness of group discussions	**	na	4.63
23.	Term project	**	na	4.66
24.	Helpfulness of lab exercises	**	3.59	4.77
25.	Student group projects	**	na	4.53
26.	Case studies or role playing	**	na	na
27.	Course journals	**	na	na
28.	Instructor's use of computers	**	na	4.45
29.	My learning increased in this course	3.51	3.39	4.69
30.	I made progress achieving objectives	3.44	3.22	4.15
31.	Interest in the subject area increased	3.45	2.89	4.46
32.	Course helped me think independently	3.50	3.28	4.69
33.	Course actively involved me in what I learned	3.58	3.17	4.69
34.	I studied and put effort into this course	3.57	3.72	4.23
35.	I was prepared for each class	3.33	3.17	3.69
36.	I was challenged by this course	3.62	3.94	4.07

NOTE: \*\* Means not reported

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## HANDS-ON PHYSICAL SCIENCE COURSE AT RADFORD UNIVERSITY

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Most students in our introductory physical science course are elementary education majors. We are faced with several obstacles in teaching basic science to these students. For example, they lack interest in science, logical thinking, and necessary data gathering and analysis skills, among others. Many of those obstacles could be traced back to the science courses they had taken in the past. Those courses put more emphasis on memorizing scientific facts than understanding natural phenomena or experiencing scientific methods. As a result, the students tend to have a negative attitude toward science in general.

In order to reverse this attitude, we have been developing a hands-on, experience based physical science course. In each class students are asked to perform several experiments which require observation, data gathering, and analysis. The instructor provides necessary scientific background and explanation on the experiments as they go. One of the experiments the students enjoyed a lot is the measurement of average speeds of cars. They actually go out on the street and take data. Through this course students can experience how science works and learn that science could be more exciting than just memorizing.

Physical Science 350 at Radford University is an introductory science course that covers a broad range of subjects including physics, chemistry, astronomy, and biology. There is no prerequisite to take this course. About 90% of students taking the course are elementary education majors. It is a part of their degree requirement to take at least three science courses. Teaching basic physical science to these students poses several obstacles to us.

The biggest obstacle is probably the education majors' lack of interest in science. They are not very excited to be in the class. To put it simply, they hate science. It is very difficult to teach anything to unmotivated students. Also, there exists a general math phobia among the students. They fear mathematical equations and are not very competent in basic algebra. For example, many students had a hard time solving the equation,  $\text{speed} = \text{distance}/\text{time}$ . They can calculate speed given distance and time, yet they get lost if they are asked to find time or even distance when given this equation.

Another problem with the students taking PHSC-350 is that they do not have the right problem solving skills. They do not look at problems in a systematic way or arrive at logical



conclusions from their observations. They also lack data gathering and analysis skills. For example, they have difficulty constructing a table of data that presents the data in a clear manner, and they also have problems simply graphing the data from such tables.

Many of these problems could be traced back to the science courses the students had taken in the past. According to the students, those courses emphasized memorizing scientific facts rather than either understanding how things work or applying scientific methods. These courses introduced many abstract concepts and the students had a hard time applying those concepts to everyday phenomena. In addition, the students could have been weak in math to start with and that may have pushed them toward less math intensive sciences such as biology. In fact, many education majors take biology courses instead of physical science to fulfill their degree requirement for the stated reason that they were deliberately avoiding math. Only a few had taken chemistry and none had taken physics in our class.

All these factors add up to the students' negative attitudes towards science in general. In order to reverse this attitude, we at the Department of Chemistry and Physics at Radford University have been developing a hands-on, experience-based physical science course. Our foremost objective is to make science more fun to the elementary education majors. Unless they enjoy science, their future students--when they becomes teachers themselves--are also not going to enjoy science.

Secondly, the students need to "do" science. They need to perform laboratory experiments by themselves and observe outcomes with their own eyes. Along the way, they need to pick up qualitative observation skills, measuring skills (using metric units!), data gathering and analysis skills, and how to reach logical conclusions. The students need to go through the entire scientific method by themselves without the instructor dictating every step of the way.

The experiments should not require any fancy setup. The students could be intimidated by the sophisticated instrumentation alone. Rather, the experiments should be simple and easy so that the students could repeat them at home or in their classrooms using common household items. The students should find out that science does not need fancy equipment.

Finally, as many everyday applications as possible should be presented. By learning how

things work, the students would be able to see usefulness in and applications for science.

To achieve these objectives, we have set up the PHSC-350 in the following way. In each class students are asked to perform several experiments which require observation, data gathering, and data analysis. The instructor provides any necessary scientific background and explanation for the experiments as they go. Lecture time is typically no more than 15 minutes. The students either get bored or lost if the instructor keeps talking. Sometimes the lecture is given at the beginning of the class, sometimes during the middle, and sometimes at the end. It depends on what is appropriate for the lab. The students are required to keep journals of what they did in the class.

Because the students are not very excited about science, we try experiments with unexpected or dramatic outcomes, such as a change in color, something that makes noise, or something game-like. These experiments tend to be more "do it once and see" and less repetitive. However, we try to make the experiments more quantitative whenever possible and introduce many data analysis skills including the construction of tables of data, calculating average values, and plotting data. Also, we have them use simple instruments such as rulers, stopwatches, scales, and graduated cylinders.

The experiments are chosen so that the students could relate them to everyday phenomena. One of the most popular experiments is the measurement of average speeds of cars on a street. They go outside, pick two points on the sidewalk and measure the distance between them with a trundle wheel. Then, they time how long it takes for a car to travel between those points. In class they are asked to calculate the average speed of each car and find the average value for 10 cars. The students enjoy this experiment because they can see how the definition of the average speed is used and they are able to measure the average speeds by themselves. We have developed a lab manual containing nearly 40 similar experiments covering physics, chemistry, astronomy, meteorology, and biology.

To evaluate each student's performance in class, we emphasize exams less and put more weight on homework problems. We try to emphasize problem solving and analyzing natural phenomena more than memorizing facts. Also, the lab notebook occupies a substantial portion of the total grade. Grading lab notebooks encourages students to pay more attention

in class, to go over the notes and complete them after class, and to come to class and do the experiments. In the future, we will be evaluating the development of the experimental skills of the students.

After one semester, the reaction of the students has been very encouraging. The most common comment in the student evaluation forms is that they liked the class because they "did" many experiments. That's exactly what we were hoping to hear. In the future, we would like to put more inquiry based teaching methods and interdisciplinary projects that involve many different concepts in physical science. ■

## **PREPARING PRESERVICE TEACHERS FOR THE EXPERIMENTAL DESIGN AND DATA ANALYSIS SOL'S**

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Many elementary teachers find teaching the science Standards of Learning (SOL) difficult [1, 2]. Some are even threatened by them. Of particular concern are the SOLs related to experimental design, handling data, and the scientific method. A possible reason for this discomfort is because many of these elementary teachers have had limited-to-no exposure to experimentation. As one of the activities included under a recent National Science Foundation Science Teachers Enhancement Project (STEP) grant awarded to Hampton University in conjunction with Virginia Union University and St. Paul's College, we included a teacher science fair competition. A special workbook/text was developed for this project, and used to guide teachers through the research process; from observation, and hypothesis formation and testing through the evaluation of data and drawing conclusions from the experiment. Twenty-two teachers from the Richmond metropolitan area and King and Queen County developed individual projects (laboratory research), and prepared written reports and display boards to present their results. Projects were adjudicated by staff at the Science Museum of Virginia in a formal competition for teachers. Several teachers admitted that this was the first time that they had actually performed a full experiment. All participants agreed, at the end, that they had a much better understanding of the process, and would be better able to teach it to their students. This successful activity is being submitted to the review panel as a reproducible model which affords preservice teachers an opportunity to strengthen their research skills. It can also make teachers feel more confident, and equip them to do a better job of teaching this block of SOLs.

The Commonwealth of Virginia has adopted Standards of Learning (SOL) testing as a means of testing the effectiveness of its public schools. Beginning in 2004, students will need to pass at least six end-of-course tests in order to graduate. By 2006, at least 70 percent of a school's students must pass these tests in order for a school to retain its accreditation. If Virginia's new accreditation requirements for public schools had been in place last spring, based on the results of the Standards of Learning tests, only 39 of the more than 1800 public schools would survive [3, 4].

The situation is critical and is causing great concern and apprehension on the part of the various "stakeholders" [5]. Now that the test is in place, and has been administered, how do we prepare our students to pass it? Dr. William C. Boshier, Superintendent of Chesterfield County Schools, is considering incentives for schools that achieve. Many parents and others

do not concur; they believe that incentive money should be used differently, (i.e. to purchase materials for teachers) [6].

Some observers are suggesting that teachers need to go back to school for retooling. According to Patricia Wright, state director of secondary education, there has occurred a content change in the kindergarten through 8th grade [2]. In some disciplines, the new standards have pushed more advanced concepts into earlier grades, thus creating a situation where schools, and teachers, must play "catch-up."

What can we do, as training institutions, to assist the preservice teacher in preparing to work with the science SOLs? This paper addresses preservice training specifically for the SOLs in experimental design and the analysis of data.

Recently, under the previously mentioned Science Teacher Enhancement Project grant, funded by the National Science Foundation, twenty-two teachers, from the surrounding Richmond metropolitan area worked together, over a period of three years, to explore innovative teaching strategies for middle school students. The approach of choice was called "Science At Your Reach." The emphasis was on enlightened science teaching, while using materials which are readily available in any environment (i.e. cups, straws, cans, popcorn, etc.) When asked about their own backgrounds in designing and implementing research projects in the classroom, many, if not most, of the teachers indicated that they had either not had very much experience, or it had been so long ago that they felt inadequate in this area. In response to this, the "Teacher Science Fair" was born. Structurally, it paralleled the student science fair. Teachers were required to identify an idea, research that idea in the library, develop a hypothesis, test that hypothesis, generate data and analyze it, prepare data tables, and draw conclusions. At the end of this process, each teacher was asked to prepare a display board to present his/her findings, and stand by the exhibit to answer questions posed by judges from the Science Museum of Virginia. The project lasted about two weeks.

What began as a simple classroom/workshop activity has developed into a training unit with multiple applications. For preservice teachers, it affords them the opportunity to look at the SOLs from the vantage point of the students they will be serving. The workbook designed for this project takes the student through all the steps of the research process, and,

along the way, provides short descriptions of each stage. Through carrying out a detailed laboratory investigation, preservice teachers can master the basic scientific processes - classifying, controlling, defining operationally, interpreting data, measuring, using numbers, using space/time relationships, designing experiments, formulating models, hypothesizing, inferring, observing, predicting, and questioning.

The module provided a strong foundation in the research process, thereby reducing fear of research. This process improved classroom performance in teaching the SOLs. ■

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## ADDRESSING PROSPECTIVE ELEMENTARY TEACHERS' BELIEFS ABOUT THE NATURE OF MATHEMATICS: A CASE FOR EXPLORING STUDENTS' CONCEPTIONS OF MATHEMATICS IN A MATH EDUCATION COURSE

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Our challenge in preparing Virginia's K-8 teachers in mathematics is a complex one. Additional requirements, including more challenging math content courses or more innovative pedagogical courses, may provide part of the solution. It is the premise of this paper, however, that additional knowledge and skills are not enough. In order to prepare teachers who will engage in current best practice pedagogy, we must also address teachers' attitudes and dispositions, their beliefs and conceptions of mathematics itself. This paper will attempt to justify this position. It will also describe strategies used in the *Inquiry in Mathematics* course in Mary Baldwin's MAT program intended to elicit and address graduate students' current, sometimes limited (if not erroneous), notions about what mathematics is really about.

*One's conception of what mathematics is affects one's conception of how it should be presented. One's manner of presenting it is an indication of what one believes to be most essential in it...The issue, then, is not What is the best way to teach? But, What is mathematics really about? [1]*

Our challenge in preparing Virginia's K-8 teachers in mathematics is a complex one. Additional requirements, including more challenging mathematics courses or reconceptualized education courses, may provide one piece of the solution. It is the premise of this paper, however, that additional knowledge and skills are not enough. In order to prepare teachers who will engage in "current best practice pedagogy", we must also address teachers' attitudes and dispositions, their beliefs and conceptions of mathematics itself. This paper will attempt to justify this position and to describe an innovative mathematics course that is taught as part of Mary Baldwin College's Master of Arts in Teaching program.

Thompson has stated that for many people "knowing mathematics is equivalent to being skillful in performing procedures and being able to identify the basic concepts of the discipline" [2]. I would propose that many of our prospective elementary teachers hold this



belief, having formed it inductively based on repeated school mathematics experiences in which the focus was mimetic teaching of procedural knowledge, followed by repetitive practice of a skill. In addition, the elementary mathematics curriculum experienced by these students -- pre-1989 and thus pre-NCTM Standards -- was likely to be one dominated by arithmetic.

My research on teachers' conceptions of mathematics had results somewhat contrary to Thompson's comment, however: 68% of participants agreed most strongly that "mathematics is a process by which people attempt to solve personally-meaningful problems", while only 25% defined mathematics instrumentally as "a set of rules, facts, and skills which we should teach to children because of their usefulness for later adult lives" [3]. This suggested that teachers have heard the message of the National Council of Teachers of Mathematics, perhaps through staff development sessions. My observations in these teachers' classrooms, however, revealed the difficulty of enacting a classroom math program that truly reflected this philosophical stance: only one participant seemed to be able actually to change her classroom practice toward real problem-based instruction. The teachers I studied seemed to "talk the talk", but not "walk the walk" when it came to mathematics reform.

So what to do about this? One possible obstacle to enactment of truly reformed math programs is suggested in the science education research dealing with the role of *misconceptions* in learning new concepts. I would suggest that teachers' strong, internal conceptions of mathematics as a rule-driven manipulation of symbols, formed over their years as students in traditional mathematics classrooms, might be viewed as misconceptions of the nature of mathematics. For us, as teacher educators, to simply tell them a "more correct" definition is surely an ineffective approach to addressing the problem.

The science education research also suggests a possible solution. Just as science lessons must confront learners with their misconceptions and present them with tasks which challenge these notions, so may we follow this approach with our prospective elementary mathematics teachers. I would propose that we must, as teacher educators, plan instruction which brings teachers' conceptions of the nature of mathematics out in the open, to be examined, compared with others', and discussed. A one-shot discussion is, of course, not likely to create permanent change, but it is a start. Prospective teachers must put their current beliefs "on the table" and

must confront contradictions between these beliefs and current research in both mathematics and psychology.

In an innovative course in Mary Baldwin's Master of Arts in Teaching program, I attempt to address teachers' misconceptions in a conscious way.

A brief overview of the course content and goals should be helpful. The graduate level course, *Inquiry in Mathematics*, is one of a series of six "inquiry" courses intended to strengthen students' backgrounds in the liberal arts, while also challenging them to explore the nature of each discipline. In *Inquiry in Mathematics*, for example, students learn new mathematics content, but also consider how mathematicians do their work and how the discipline as a whole builds its body of knowledge. By understanding what it means to do mathematics, as opposed to know mathematics, teachers can plan lessons that put students in the role of mathematicians, using the techniques and processes inherent in the discipline.

The course is organized into various strands, such as "What is mathematics?", "How do children learn mathematics?", and so forth, with the content strands (number theory, geometry, probability) interwoven. Students spend time during the initial weeks exploring the nature of mathematics through activities which are intended to probe their current conceptions of the nature of mathematics. This leads logically into a second strand on the history of mathematics, which reinforces the idea that mathematics is a human endeavor; students' group research projects introduce the class to some of the great (sometimes quirky, sometimes inspiring) characters who have worked in the field of mathematics. One activity within this strand is the viewing of the *Nova* episode "The Proof" which follows Andrew Wiles' experiences as he solved Fermat's Last Theorem; class discussion on this often revolves around the surprisingly passionate way this mathematician talks about his work. It also highlights the interdependence of those in the field as they build research on the proofs of those who went before.

This glimpse of a modern mathematician at work leads students into the next strand in which they do library research on some topic in mathematics which is currently being studied; the results are presented as oral reports to the class. This assignment is one which is difficult for students, but its successful completion sends several messages: (a) mathematics goes well

beyond the arithmetic with which they are all so familiar; (b) mathematics is not a finished product; and (c) the students are themselves capable, to some extent, of understanding these new topics— a real confidence-builder! In past semesters, the class has been treated to some wonderful presentations on such topics as fractals, topology, and chaos theory.

I will close with one example of the type of activity that seems to have successfully elicited students' conceptions of mathematics, bringing them out for examination, discussion, and sometimes revision. Students are given cards on which are written quotations about the definition or nature of mathematics, and they are asked to put them into three piles: "I agree", "I disagree", and "I don't understand this". With a partner, they compare and discuss the sorting. Cards in the "I don't understand this" pile are brought to the whole class, to pool students' interpretations. Finally, in a "whip-around", students choose one quotation that seemed particularly meaningful or helpful to them and explain why it seemed so.

You may at this point be asking "Where's the math content"? We are all aware that a number of our prospective elementary teachers do arrive in our classes with gaps and weaknesses in their knowledge of mathematics content, and as teachers of these students we have an obligation to strengthen that knowledge. The content strands of this course, such as number theory, are intended to do just that. In addition, however, they also serve as starting points for discussing pedagogy (as I attempt to model a problem-based approach to teaching mathematics); they give students experience in group problem-solving; and they provide a context in which students improve their communication skills through presentation of solutions, oral reports, and demonstration of models.

In summary, this mathematics education course is intended to prepare prospective teachers for "best practice" in their classrooms by modeling instructional strategies which may be quite different from what they experienced themselves as elementary students. The course builds their understanding of important concepts and skills in mathematics, but it also takes into account that other important facet of curriculum: beliefs, dispositions and attitudes. By consciously addressing teachers' conceptions of what mathematics is, we can help them build richer images of the nature of mathematics, for the benefit of their future students. ■

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# **AN INVESTIGATIVE APPROACH<sup>1</sup> TO TEACHING MATHEMATICS: EXCITEMENT AND CONCERNS OF K-8 PRESERVICE TEACHERS**

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Following from the recommendations of the National Council of Teachers of Mathematics, an Investigative Approach (IA) to teaching mathematics encourages students to explore real-world problems through hands-on activities instead of focusing on rote memorization of facts, formulas, and procedures. This paper discusses thirty-two K-8 preservice teachers' responses to questions regarding excitements and concerns about using this method of teaching. Although most preservice teachers are excited about the prospects of using this approach in their future classrooms, some exhibit hesitations related to concerns about time constraints and their own math abilities. A mathematics methods course presently being taught that is centered around the ideas of IA is discussed, and recommendations for the use of IA in preservice math methods courses to help teachers overcome these concerns are made.

Following from the recommendations of the National Council of Teachers of Mathematics (NCTM) [1], an Investigative Approach (IA) to teaching mathematics [2] encourages students to explore real-world problems through hands-on activities instead of focusing on rote memorization of facts, formulas, and procedures. Many preservice teachers are excited about the prospects of using methods associated with IA in their future classrooms; however, some teachers have concerns and hesitations about using this approach. This paper discusses thirty-two K-8 preservice teachers' written responses to questions regarding their feelings toward using IA for teaching mathematics. Further, this paper discusses a mathematics methods course presently being taught that was developed around the ideas of IA [2] and how this course attempts to help teachers overcome some of their concerns.

## **The Investigative Approach**

As described by Arthur Baroody [2], IA embodies three central ideas of the NCTM for teaching K-8 mathematics: 1) Math should be purposeful and made relevant to children's

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<sup>1</sup> I would like to thank Arthur Baroody for his guidance and mentoring as he helped me develop my own investigative approach to teaching mathematics. The math methods course that I presently teach is based on my work with him at the University of Illinois at Urbana-Champaign and his mathematics teacher education curriculum [2].

everyday life; 2) Math should be problem-based and inquiry-based; and 3) Math should be understandable and meaningful. More specifically, the aim of IA is to foster in students a positive disposition toward mathematics and an ability to conduct mathematical inquiry and to promote mathematics as a way of thinking [2].

Teacher instruction within IA builds on the ideas of learning as a social process [3, 4] and on the belief that knowledge is best learned if constructed by students [5] and connected to their own informal ideas of mathematics [2, 6]. Instead of rote memorization, children are given opportunities to meaningfully memorize facts and procedures [7] which further promotes an ability to apply knowledge to novel situations [2]. For example, students investigate why  $3 \times 4$  equals 12 and how this fact can be used to figure out  $12 + 4$ . By using IA in K-8 math methods courses, these ideas can be instilled in preservice teachers.

### Survey of Teachers' Thoughts on Implementing an Investigative Approach

Thirty-two K-8 preservice teachers in two sections of a mathematics methods course were asked to respond to the following questions:

- 1) Thinking about the Investigative Approach to teaching mathematics, list at least 3 concerns or hesitations that you have about using this method in your future classrooms.
- 2) Thinking about the Investigative Approach to teaching mathematics, list at least 3 things that excite you about using this method in your future classrooms.

Responses to these questions were used as motivation for a class discussion centered around implementing IA and serves as the main source of information for considering preservice teachers' excitements and concerns.

### Preservice Teachers' Excitements about Using an Investigative Approach

The excitements associated with using IA expressed by the 32 preservice teachers tended to fall into three categories: 1) Emphasis of hands-on activities; 2) Focus on understanding; and 3) Encouragement of inquiry-based learning. Teachers seem to be most excited about the hands-on nature of IA. As one teacher wrote, IA ". . . makes math fun and interesting. Kids love hands-on materials." Another teacher described IA as ". . . hands-on with a meaningful purpose," and yet another was excited about using IA because "hands-on activities (are)

remembered longer than math problem sheets." The following comment reflects the sentiment of most preservice teachers' excitements about IA's promotion of understanding: "It (IA) encourages students to discover principles and understand why things work not just how (emphasis added)." Most teachers were also excited about the encouragement of inquiry-based learning within IA. This was reflected in comments suggesting that the approach creates an "atmosphere of curiosity in the classroom," and provides "more opportunity for the children to explore." This approach, "engag(es) students in a more reflective style of learning, i.e. thinking through problems rather than rote spouting," wrote another teacher. Overall, teachers comments seemed to express enthusiasm about the possibilities of using IA in their classrooms.

### Preservice Teachers Concerns about Using an Investigative Approach

The concerns and hesitations of the 32 preservice teachers tended to fall into two categories, time constraints and their own math ability. With the recently implemented Virginia Standards of Learning (SOL) [8] and corresponding Standards of Learning exams, many teachers expressed concerns about "having enough time to cover SOL material and still give them [students] plenty of time to explore the manipulatives." Based on student-teaching experiences, one preservice teacher wrote: "There have been days when I've been lucky to have 45 minutes of continuous math time. I don't think that is enough time to let the kids explore."

Some preservice teachers were also concerned about "having sufficient knowledge . . . to facilitate their [students'] learning." Another teacher questioned, "What will happen when one of my students poses a problem that I should know but can't come up with anything?" Another teacher wrote, "I'm not sure I understand how to use all of the manipulatives, so how do I help my kids understand?" Although other concerns were expressed, time and ability tended to be the two most recurring concerns.

### Overcoming Concerns Through the use of an Investigative Approach in Math Methods Courses

The K-8 math methods course taught by the author was developed to model IA for teaching mathematics. Preservice teachers investigate mathematical ideas, children's understanding of mathematics, and pedagogical content knowledge through hands-on, cooperative, inquiry-based activities. One goal of the class is to build on teachers' excitements



about IA and use this to help them overcome their concerns and hesitations.

As documented above, preservice teachers expressed concerns about having enough time to teach all of the prescribed curriculum (e.g., Virginia SOLs). In the methods course, lessons are integrated with literature, social studies, science, and writing which models for teachers ways of saving time by covering several topics in one lesson. For example, instead of discussing how math and literature can be integrated in their future mathematics lessons, teachers are involved in using Tangram puzzles to create animal character shapes and discuss geometric shapes as a children's story book, *Grandfather Tang's Story* [9] is being read to them. Preservice teachers also plan, present, and discuss integrated lessons. They are often amazed at the number of different concepts and ideas (e.g., SOLs) included in their lessons. Ultimately by using these techniques in their own classrooms time is saved and children are more likely to remember and understand [10]. As one teacher pointed out, "Kids come to understand the concepts and over the long run, time is saved because concepts won't need to be re-taught from grade to grade."

Preservice teachers also expressed concerns about their own math ability. In the methods course, questions and conflicts serve as situations for exploration. This is modeled by exploring students' questions that arise as part of the activities. Teachers are involved in activities that lead them to ask questions such as, "Is 0 odd or even?" or "How can I help children decide if  $4/0$  is possible?" When questions are asked, the class works together to answer the question. By using these techniques in their own classrooms, teachers' short comings may serve as opportunities for exploration and in essence they can learn with their students.

## Conclusions

It is important for teacher educators to be aware of concerns that many preservice teachers have, especially those related to time and ability, that may impede them from actually implementing IA in their classroom. By building on teachers' excitements, some of their concerns about using IA can be overcome. Teachers tend to teach as they have been taught. Through immersion in a methods course that embodies the philosophy of IA, preservice teachers witness teaching and learning that is inquiry-based. Consequently, they will be more prepared and confident with the methods and thus may be more willing to explore mathematics

with their own students through hands-on, inquiry-based activities. ■

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# **IMPACT OF A NEW INTRODUCTORY MATHEMATICAL MODELING COURSE ON STUDENT CONFIDENCE IN MATHEMATICAL ABILITY AND SKILLS**

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Interdisciplinary mathematics and science courses are increasing in popularity. Faculty teaching these courses are given the opportunity to show how mathematics plays an important role in science and how it can be used to improve our understanding of mathematics and science. This paper discusses a new course in mathematical modeling that focuses on environmental issues. Course content and format are presented, as well as the results of a study on the changes in students' perceptions of their mathematical abilities as a result of taking this new course.

## **Introduction**

Environmental Mathematics is a new course at Mary Washington College developed under the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) grant. The course was designed for students who are not necessarily mathematics or science majors, but are interested in environmental issues. The developers of the course hoped that the focus on environmental data sets would show how naturally mathematics enters into our daily lives and how it can be used to better understand environmental phenomena. Mathematics is presented as an essential part of science rather than as a separate isolated topic. The course aims to enable students to understand the "mathematical perspective" as they attempt to find solutions and obtain a better understanding of the phenomena they are studying.

## **Course description**

Although primarily a lecture course, class time is allotted for group activities, discussions, videos, and guest lectures. The first half of the semester is spent on families of functions and curve-fitting techniques. Linear, exponential, power, and logarithmic functions are presented along with environmental examples that display the behavior modeled by these functions. The method of least squares is presented, followed by transformations to linearity using logarithms and goodness-of-fit measures. During the second half of the semester, sequences and difference equations are presented as a method for modeling data collected over time. The

method of undetermined coefficients is presented for solving first-order difference equations that model diverse situations. Mathematical topics also include the logistic function, chaos, fractals, probability models, and patterns in nature. The text for the course [1] covers each of these topics with the exception of probability models.

Various environmental data sets are explored throughout the semester. Population growth and decay, air and water pollution, the use of natural resources, epidemics, genetics, natural disasters, and weather are studied using models from one or both parts of the course. As much as is possible, real data sets from scientific journals are used for class examples and student projects. Although mathematical modeling is presented as a process that scientists use and these students are learning basic modeling techniques, the course follows the pattern for mathematics education suggested by Rublein [2].

Students use graphing calculators and other forms of technology on a regular basis to facilitate model fitting and classroom examples. The TI-82 graphing calculator is used beginning with the first day of class to graph and study data that the students have collected. Calculator use increases in the course as students learn modeling techniques and methods for comparing models. Students become adept at graphing both data and the associated functions and with interpreting their results. In addition to the graphing calculators, the SPSS statistics software is employed as a supplement to graphing calculators for regression and correlation analysis. Two additional software packages, "Fractal Attraction" and "Interactive Differential Equations," are used to enhance the coverage of fractals and chaos.

### **Student evaluation**

In addition to midterm and final exams and regular homework assignments, students complete several writing assignments over the semester. These assignments require students to describe an environmental issue or problem, describe how a mathematical model is used, and what conclusions can be reached. The first assignment requires students to read and summarize an article discussing an environmental issue. Each of the articles contains one or more graphs that students must describe. Discussing the article and describing the graph(s) gives students the opportunity to connect the data with a possible model for the observed relationship and make conclusions about the environment. The topics of articles that have been assigned include sustainable management of tropical forests [3], climate models [4], and

population growth [5].

Students complete two group projects that also require a written report of their research and data analysis. These group projects are presented to the class as posters in which students are expected to describe the environmental issue the project addresses and the model they used to analyze the data. The first project involves regression techniques for choosing a best-fitting model. Project topics include monitoring the population size of endangered species [6] and assessing the relationship between the size of harvested trees and their value [7]. The second project requires students to use difference equations to model possible situations involving types of pollution or managing the population size of animals in a wildlife refuge.

### Course evaluation

Students completed pre-course and post-course surveys to assess the impact of the course on student perception of their confidence and skill in mathematics. The surveys asked students to indicate the degree to which they agreed with a list of statements. The statements included in the pre-course survey are in Figure 1. Average responses for the Spring and Fall 1998 semesters, as well as the combined results for both semesters, are given in Table 1. Questions for which a paired t-test indicated significant improvement in attitude over the semester are indicated. Although the responses are paired, since pre- and post-course responses were recorded for each student, average responses are given as a basis for comparison. While there are some differences between the two semesters, in general students began the course with attitudes regarding their mathematical abilities that are somewhere between "neutral" and "agree." Both classes showed significant ( $p$ -value  $< .05$ ) improvement in students' confidence in mathematical abilities. The class in the Spring semester showed significant improvement in students' confidence in computer skills. Students in the Fall semester showed less significant improvement ( $p$ -value  $< .10$ ) in confidence in their calculator skills and in their opinion on their performance on tasks that require the ability to apply information or use analytical skills. No improvement was seen in the Spring semester in these same areas, perhaps due to the fact that those students began the semester with a higher degree of confidence in those areas.

Please indicate in all honesty to what extent you agree with the following statements:

1 = strongly disagree    2 = disagree    3 = neutral    4 = agree    5 = strongly agree

Overall, I would say that I have a high level of confidence in my mathematical abilities.

Overall, I would say that I have a high level of confidence in my computer skills.

Overall, I would say that I have a high level of confidence in my calculator skills.

I typically perform well on tests/assignments that ask me to apply information.

I typically perform well on tests/assignments that ask me to use analytical abilities.

**Figure 1.** The pre-course survey

**Table 1.** Average responses for the pre- and post-course surveys.

	Spring 1998 (n = 10)		Fall 1998 (n=13)		Combined	
	Pre	Post	Pre	Post	Pre	Post
High level of confidence in mathematical skills	3.20	3.70**	3.46	3.85**	3.35	3.78**
High level of confidence in computer skills	3.20	3.90**	3.08	3.15	3.13	3.49*
High level of confidence in calculator skills	3.90	4.00	3.31	3.85*	3.57	3.91*
Perform well on tasks that require applying information	3.80	3.80	3.23	3.69*	3.48	3.74*
Perform well on tasks that require analytical abilities	3.70	3.70	3.46	3.77*	3.57	3.74

Key: \* indicates significance of the paired t-test for improvement at the 10% level of significance. \*\* indicates significance at the 5% level of significance.

The post-course survey had two additional questions that measured students' perception of their insight into the integration of mathematics and science and addressed students' understanding of environmental issues. Average responses for both semesters and the combined results are given in Table 2. Responses show that students left the course with the

perception that they had gained knowledge about the association between mathematics and science and on issues concerning the environment.

**Table 2.** Average responses on the post-course survey

	Spring 1998	Fall 1998	Combined
Greater insight into integration of math and science	4.30	4.21	4.25
Better understanding of some environmental issues	3.60	4.29	4.00

### Conclusions

Mathematics faculty hope to give their students not only the ability to use mathematics, but also an appreciation of the vital role that mathematics plays in our lives. Of utmost importance is that students develop confidence in their abilities to apply mathematics. The combination of course content and assignments in this new course has resulted in an improvement in students' perceptions of their confidence in their mathematical abilities and improved their knowledge of environmental issues. Student confidence was bolstered by an acquisition of technical and analytical skills as well as an increase in mathematical and environmental knowledge. ■

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# **INFORMAL GEOMETRY IN THE PREPARATION OF TEACHERS: A NEW MATHEMATICS COURSE AT THE UNIVERSITY OF VIRGINIA**

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Students require a rich variety of hands-on geometric experiences before they progress to more formal traditional geometric instruction. This fact has often been ignored in the mathematics preparation of today's teachers. At the University of Virginia a new general education geometry course, *The Shape of Space*, is being developed that focuses on obtaining deep understandings of elementary geometry through physical and visual activities.

## **Introduction**

Deficiencies in the geometry education of American students have long been observed and documented. Geometry occupies a central place in the elementary and middle level mathematics curriculum, and geometric concepts, representations, and patterns contribute to students learning measurement and number concepts. Notwithstanding this central role, this material has been neglected to such an extent that in 1993 Geddes and Frotunato [1] stated that ". . . many middle grades students could be described as geometry deprived" (p. 212) and argued further that this deprivation is a likely impediment to the student's mathematical progress. This deprivation was prominently documented in the Third International Mathematics and Science Study (TIMSS) [2] which identified geometry and measurement as the only areas of mathematics where American 8th graders fall notably below the average of the 41 participating nations.

Our geometric deprivation in Virginia is currently partially hidden by the fact that the SOL Geometry test scores were better than the Algebra test scores, but the belief that this issue can temporarily be put off is based on a misinterpretation of the data. In fact, the geometry tests were taken by the much smaller and more select group of students that had taken geometry. When, in the future, the geometry test is administered to (almost) all students, we will likely discover that the geometry scores will cause intense alarm.

Two further observations are critical to my thesis. The first is that geometry is learned developmentally, and the developmental process can not effectively be bypassed. It is only a slight exaggeration to assert that when children do not have an appropriately rich developmental sequence of informal geometry experiences in which they are learning through their eyes and fingers, they do not learn geometry. And, without these experiences their overall mathematics development, especially that which rests on non-routine problem solving and critical thinking skills will suffer.

The second observation is that most children today are living in a geometry void. This is an obvious point, but one that is often ignored at the expense of our children. The active life of building, storing, measuring, sewing, and cooking that once was common in America is gone and has not been replaced with one of equal educational power. Nothing in their daily life, outside of cars, video games, and athletics, requires measurement, geometric awareness and analysis, or visualization. If students are to find the essential informal geometry experiences that once were part of daily life, a preponderance of those experiences must come from within the schools.

By and large, this geometry is absent in today's schools and few of our teachers are prepared to teach the hands-on geometry that is needed. In Virginia the seriousness of these dimensions is magnified by the Teacher Licensure Requirements that we have discussed at this conference. Our teacher preparation programs must include a new geometry dimension or our children will suffer.

### **A Response**

As part of the NSF collaborative VCEPT, the University of Virginia is responding to these concerns by developing a new general education geometry course that is primarily focused on the needs of future K-8 teachers. The course is a 100 level course in informal geometry titled *The Shape of Space*. Currently it is being piloted for the second time and will be submitted for College approval this spring. The course title attempts to capture the flavor and philosophy of the course. To the extent the course is successful, students in *The Shape of Space* divide their time between geometry activities involved with drawing, building, coloring, measuring, and analyzing. Communicating what they learn is also stressed. This is our goal but candor requires an admission that the goal is not always reached.

When approved *The Shape of Space* will be a three credit course with two hours of lecture and two hours of laboratory. At present the course is divided into three approximately equal sections. The first part consists of measurement and estimation activities of a highly hands-on nature. This includes working with rulers, protractors, compasses, strings, and calipers. The conceptual development of geometry is built upon a foundation of activities where students measure, calculate and estimate lengths, areas, surface areas, and volumes.

A separate module is spent on analysis of geometric shapes, properties, and concepts. Students explore basic topics such as angle sums for triangles and properties of parallel lines. Paper folding is a large part of this section of the course. A few investigations of how these properties might change in a curved space together with geometric explorations on the surface of a balloon are included.

The final part of the course explores symmetry and other geometric properties from a transformational viewpoint. In this piece elementary symmetry groups, symmetry patterns, and tessellations are discussed. Similarity and proportional reasoning are also included here.

The universal problem of overly zealous teachers with too much material and too little time occurs in this course. Perhaps, because the goal is to overcome a lifetime of sensory deprivation in one semester, the problem is worse here than in many other subjects. However, this kind of geometry is fun and it is my firm belief that the exact topics covered are not of primary importance. What is most important is the active engagement of future teachers in geometric explorations and analysis. Teachers need to experience geometry and know that it is fun. We have failed whenever a teacher enters their profession without ever having smiled while holding something in their hands and saying, "Oh! I see!" If this is not happening, our efforts are not on target. Students need experiences in building, visualizing, and figuring things out. They need to do this at developmentally appropriate levels, and in my view this means that they need to experience success in finding explanations of phenomena that interest them.

### Supporting Theory

There are three axioms which underlie this course, its philosophy, and its format. First is the body of research centering on the so called van Hiele Model of how children (and adults) learn

geometry [3], [4]. Children do not succeed in geometry if their development of understanding is at a different level than the instruction they are receiving. A second axiom is a personal article of faith that elementary geometry is an empirical science. Its roots are all based in experience and observation. This is a non-technical personal expression of truths similar to those behind the van Hiele model. Teaching and learning geometry will succeed when students come to geometry classes with a sufficiently rich treasure of experiences that combine physical manipulation, visualization, exploration, and analysis. Finally, informal geometry is the foundation on which children build much of their mathematical and scientific world. I believe, as Hilton, Holton, and Peterson [5] stated, that algebra gives us tools for solving problems, but geometry gives problems that we wish to solve. ■

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## ON THE JOB MATHEMATICS

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What kind of course work is appropriate for a general education mathematics requirement? In most instances, students see a presentation of one or more mathematical topics followed by some applications. Sometimes these applications are characterized as 'real world' even though no person would ever be paid to work the problems that students are given. We will describe an approach to this issue that requires students to replicate mathematical work that is done by people who want to keep their jobs. Only a small minority can make money doing mathematics for entertainment. Hence, we omit for this category everyone employed in a mathematics department. On this account, our approach is, by necessity, an interdisciplinary one.

What kind of course work is appropriate for a general education (GE) mathematics requirement? The question has been asked numerous times in numerous venues and produced numerous answers [1, 2, 3].

On this occasion, we begin with a new, or perhaps recycled, objective for such a course: Let us try to convince the GE student that mathematics can be used to help make decisions in the workplace. Perhaps a commercial version is more compelling: Let us convince the GE student that employers will pay good money to someone who can do useful kinds of mathematics.

Now, what kind of course, exactly, will accomplish this end? The following exercise is often used as a prototype for what fails to pass muster: A man can walk 5 miles per hour, and row a boat 3 miles per hour. He wishes to make regular visits to his girlfriend who lives 2 miles upstream on the other side of a 300 foot wide river with a current at 1 mile per hour. How far up the river bank should he tie his rowboat so as to minimize time of travel?

An allegedly much better problem uses some data on yields of corn per acre in the US from 1890 to 1990. The student is asked to fit a curve to this data, thereby getting practice with polynomials or trigonometric functions or exponentials.

Why is the second problem better? Presumably because it contains some real data, while the first does not. Recognizing this fault, can we repair the first problem? Suppose we name the two principals (real names, say, using volunteers from the class). We can also name the river, say, the Pamunkey, making sure we are at a place where the flow rates and river width are accurate. Alternatively, we can use whatever width and flow we observe. Have we made an improvement? Probably not. And for a good reason.

The rowboat problem does not expose a working example because real people simply do not do this particular optimization. The visitor would almost surely get in a car and drive to the nearest bridge in order to cross the river. But if that is the central objection to the rowboat problem, then we are obligated to apply the same standard to the corn problem. Who in the corn business does this curve fitting? The student is not told. Why would anyone do this curve fitting? The student is not told. What do the parameters in the fitting function signify in the context of the data? The student is not told. I am suggesting, therefore, that in spite of its use of slightly more realistic data, the corn problem is no better than the rowboat problem, at least for my intended purpose. If one is faulty, so is the other.

On-the-job mathematics enforces a rigorous theme. The owner of the problem has to take responsibility for understanding why the mathematics was done in the first place. The owner is forewarned: An action will be taken as a consequence of the mathematics. Further more, the more sophisticated, and more successful, employees have some grasp of the argument by which the mathematics was invoked. Understanding of the argument permits one to consider alternative methods or, perhaps, to determine whether non-conforming data can be managed with the mathematical procedures at hand.

What is the particular value to a GE student of a course that entails the study of mathematics in the workplace? Only this: Suppose that the student has actually had the experience of doing a piece of mathematics whose conclusion informed the student about a particular decision in an endeavor external to mathematics. I want this hypothesis to be taken literally. No rowboats used by fictitious personnel, no data analyzed without explaining who needed that analysis and why. It is my belief that such an experience could actually convince GE students that they are capable of examining problems of a quantitative nature that they might encounter in business.

In part, this conclusion arises from my intuition, or perhaps, personal taste. However, on at least two occasions at meetings dealing with quantitative literacy, I have asked interested business people in attendance precisely what mathematical tools they wanted their potential non-technical hires to have. How would they describe the mathematical background that a successful job applicant would possess? In each case, the answer was, "I don't know."

I believe, therefore, that what is needed by potential employers is primarily some confidence on the part of their employees that they can successfully attack on-the-job quantitative problems. It is traditional in mathematics training that we (the mathematicians) will show them the mathematical techniques, perhaps demonstrating those with fragments of real problems. It is not our task, and we don't want it to be our task, to expose students to the actuality of on-the-job problems. Those problems are very messy, and besides, the instructor would have to learn something outside of mathematics in order to find out why they are important. But, I would like to suggest that confidence in solving on-the-job problems comes from solving on-the-job problems.

Now, one must ask, which job? Ideally, we could predict that the GE student is going into food service, or insurance, or web-page design or dress design. This kind of prediction is, unfortunately, impossible. Nevertheless, it seems to me that it doesn't really matter what the job is. Rather, the important thing is that students recognize that correct mathematics coupled with a correct 'model' for the problem at hand is necessary to save money and, in some instances, to stay out of danger. Equally important, as I have suggested earlier, is that students recognize that they themselves can find their way through a muddle of data and solve these sorts of problems. It is inevitable that work of this kind will draw on a variety of different mathematical techniques.

In a particular GE course at William and Mary [4, 5], students use some elementary algebra, some elementary geometry, some elementary trigonometry pretty much on a just-in-time basis. There is no 'chapter' on quadratic equations, no chapter on the law of sines. But there is extensive discussion of the meaning and usefulness of the problem exercises that the students do. And there is always a discussion of why the mathematics works and what assumptions are needed to make the mathematics work. Many exercises demand that students take an algorithm apart to see what makes it tick.



There should be a number of ‘jobs’ that can serve as a vehicle for such a course. To this point, the only version at the GE level that I know of is the William and Mary example. I would like to encourage others interested in this prospect to try something of their own along these lines. ■

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## A MODEL FOR FACULTY COLLABORATION IN PREPARING VIRGINIA'S K-8 TEACHERS

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The overall goals of the Virginia Standards of Learning (SOL) [1] are for students to become good problem solvers and communicators about mathematics, to reason logically and to make connections within mathematics and to other disciplines such as in solving science problems. Unfortunately, the beliefs about teaching of many preservice teachers are not consistent with these goals. Furthermore, the college mathematics courses experienced by preservice teachers are generally in contrast to these goals. This study outlines a collaborative effort of three colleges to encourage faculty to adopt a more student-investigative style of instruction. A planning team offered a semester of workshops in which professors experienced student investigations, critiqued them, and were encouraged to try them in their classes. The data gathered from this study suggest there was success toward changing the beliefs and instructional practices of the professors to be more consistent with the stated Virginia overall goals for students.

The Virginia Mathematics Standards of Learning (SOL) outline specific goals for students at all grade levels as follows: (1) to be creative problem solvers, (2) to be good communicators about mathematics, (3) to reason logically, both inductively and deductively, and (4) to make connections among ideas within mathematics and to other disciplines, i.e., in solving science problems. These are the same goals of the *Curriculum and Evaluation Standards for School Mathematics* [2] and are representative of the current reform movement in mathematics education. Unfortunately, the beliefs of students preparing to be mathematics teachers are frequently in sharp contrast to the reform goals [3]. It has been widely reported that teachers tend to teach as they were taught. It would seem that the traditional instructional models prospective teachers have experienced as students have quite naturally influenced their beliefs about the nature of mathematics and the role of the teacher. A challenge for the reform movement has been how to break this cycle of sameness in mathematics teaching.

Most of the reform efforts have been directed toward K-12 teachers by means of summer institutes, workshops, conferences, etc. However, the most recent teaching the prospective teacher has experienced is at the college level. It is proposed that mathematics teaching at the college level is a vital and timely opportunity to influence prospective teachers' beliefs and

goals for teaching mathematics. However, changing college and university teaching proves to be a challenging situation. Many professors have had little or no training in theories of teaching and learning and have scant familiarity with the goals of the mathematics reform movement.

The concern is how to impact a change in mathematics teaching and learning along the lines of the reform goals at the university and college level. There have been some summer workshops for college and university teachers such as Project Prompt at Humbolt State University, California. Another avenue for reform has been the adoption of reform-style texts and curriculum materials such as the "lean and lively" Harvard Calculus. While these efforts are experiencing some success, they are affecting only a small percentage of college mathematics instruction. Professors frequently simply decline to attend reform workshops or to use reform texts and materials. It appears that the source of the problem is due to the lack of many professors' belief in the reform goals and consequently their continued use of traditional pedagogical methods (Larry Sowder, personal correspondence 1997). In contrast to the K-12 teacher who is generally more influenced by school district or school board decisions concerning teaching goals and curriculum materials, university teachers generally have a great deal of autonomy concerning their teaching style and choice of texts and materials and can effectively avoid involvement or influence of the reform movement.

### **Methodology**

To investigate how beliefs of university mathematics instructors might be changed to posit more value to the goals of the reform movement, a collaborative of three local universities/colleges in a large metropolitan area was established. With the support of the National Science Foundation, a planning team of four persons from the three institutions met for a year to discuss pertinent literature, establish common goals, and make a specific plan for engaging colleagues at the three schools. The team decided to use a model similar to that espoused by Carne Barnett [4] calling for frequent discussions among mathematics teachers.

The planning team wrote and tested sixteen student investigations which used cooperative learning groups and emphasized active student involvement and development of major concepts. They also included student communication through reflections and discussions. The mathematics professors at the three institutions who taught preservice K-8 teachers were

invited to attend the workshops of interest to them. The intent was to have the professors experience each activity somewhat "as a student" and then to discuss and critique the effectiveness of the activity and suggest how it might be altered for a particular course or improved. The professors were encouraged to use the activities in their current courses and give further feed-back to the group. The participants were given a token stipend for their efforts. A series of seventeen workshops were held during Spring '97 with about fifteen participants and the four planners.

Baseline data from an "Instructional Practices Scale" consisting of 21 items was collected from seven participants at the beginning of the series and from twelve participants at the end of the work-shop series, as several participants did not fill out the initial form. Means of the available data for each question was generated on the pre and post survey. In addition, a short open response follow-up survey (six questions) was sent out after the workshop series. There were eleven surveys sent with nine replies.

### **Results and Implications**

There were generally about 7-8 participants at most workshops. The sessions were consistent with the findings of Barnett in that the discussions were lively and comments centered around the mathematical ideas and how to engage students to think about them in substantive ways. The Instructional Practices Scale included eight questions pertaining to the emphases of the workshops with results as indicated in Table 1. For each area of emphasis of the workshops, the change was in the desired direction. However, this is only a rough indicator since matched pairs of data do not exist for all participants. Further statistical analysis, additional follow-up data, and possibly visits to the participants classrooms are suggested to verify if beliefs and practices were significantly changed.

The results of the open ended survey were extremely positive with almost all participants stating the workshops as "very beneficial" or "good benefit." The question "Did these meetings encourage you to continue using or to begin to use student centered activities in your teaching of mathematics?" resulted in eight replies of "yes" or "indeed yes" and one reply of "continue."

**Table 1. Questions of Workshop Emphases**

Scale: 1 never 2 seldom 3 sometimes 4 often 5 very frequent			
How frequently do you use each practice?	pre	post	delta
Active involvement of students	3.79	4.42	+0.63
Small group cooperative learning	3.57	3.75	+0.18
Problem solving as means and goal	4.00	4.33	+0.33
Student communication, orally	3.57	3.67	+0.10
Student communication, written	3.43	3.50	+0.07
Hands-on manipulatives	2.86	3.17	+0.31
Class discussions	3.71	3.92	+0.21
Activities focus on the whys and hows	3.29	3.91	+0.62

The survey on benefits of the workshop include: new approaches to ideas, very interactive, excellent collegiality, reinforcing teaching goals, getting enthusiastic, make changes for next semesters classes, "actually having time to play with the materials, sharing techniques and materials," "discussing what doesn't work," "practicing with a group led to lots of discussion and possible solutions." The replies to "Other comments?" included: It was a great experience! Thank you so much for including me on the committee; just the time we had "chatting" was so valuable, ... inspirational. Thanks! Several of the participants used some of the student-centered activities in their courses immediately and reported the results back to the group with great enthusiasm. At least two of these persons had almost never included these types of activities in their courses in the past. Many asked if we were going to have the sessions again the following semester.

While the idea of getting college teachers together to discuss teaching ideas may sound quite simple to effect, the actual planning and work took place over several years and required a large amount of time, reasoning, and commitment by the planning team. The basic outline of the plan is as follows:

- (1) Develop a cohesive and unified leadership team over a year or more.
- (2) The team jointly develops and tests student investigations with reform goals for students

for college level courses.

- (3) Faculty are encouraged to attend 2-4 workshops per month for a semester.
- (4) Workshops have participants experience an activity and then discuss and critique it and the team later provides a revised version.
- (5) A team member leads each workshop, maintaining a positive, constructive, and focused discussion with the comments of each member respected and valued.
- (6) Participants are encouraged to try the activities in their classes and to share results with the group and to share their own "student centered" curriculum materials with the group.

These data suggest that this workshop process of discussing curriculum materials which illustrate student investigations, cooperative learning groups, active student involvement, and the development of major concepts was beneficial for these college professors. The workshops were led alternately by the four members of the planning team, several of whom had no prior experience leading such sessions. We suggest that the success was due to the process and not the individuals on the planning team. It is suggested that similar workshops for university and college teachers might change beliefs and teaching practices along the lines of the reform movement. The end result would hopefully provide preservice teachers with college instruction in mathematics which models reform teaching and which would encourage them to adopt the goals of the Virginia Mathematics SOLs, i.e., students become creative problem solvers, good communicators, use logical reasoning and be able to make connections within ideas of mathematics and to other disciplines. ■

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## **EXPERIMENTAL DESIGN AT THE INTERSECTION OF MATHEMATICS, SCIENCE, AND TECHNOLOGY IN GRADES K-6**

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Interdisciplinary courses, highlighting as they do the area(s) the disciplines have in common, often give the misperception of a single body of knowledge and/or way of knowing. However, discipline based courses often leave the equally mistaken notion that the disciplines have nothing in common. The task of the methods courses described in this paper is to reach an appropriate balance so that our pre-service elementary (K-6) teachers have a realistic perception of the independence and interdependence of mathematics and science.

At the College of William and Mary each cohort of pre-service elementary teachers enrolls in mathematics and science methods courses taught in consecutive hours. Both instructors emphasize the importance of the content pedagogy unique to their disciplines such as strategies for teaching problem solving, computation, algebraic thinking, and proportional reasoning in mathematics and strategies for teaching students how to "investigate" and "understand" the concepts of science. The instructors model interdisciplinary instruction by collaboratively teaching common content pedagogy such as the use of technology, data analysis, and interpretation. Students also identify real-life application of the mathematical principles they are learning that can be applied to science. The concept of simultaneously teaching appropriately selected math and science skills are stressed. Given this approach students are not left with the notion that mathematics is the handmaid of science nor the notion that it is the queen of the sciences. Rather, they view mathematics as a co-equal partner.

Interdisciplinary courses, highlighting as they do the area(s) the disciplines have in common, often give the misperception of a single body of knowledge and/or way of knowing. However, discipline based courses often leave the equally mistaken notion that the disciplines have nothing in common. The task of the methods courses described in this paper is to reach an appropriate balance so that our pre-service elementary (K-6) teachers have a realistic perception of the independence and interdependence of mathematics and science.

At the College of William and Mary each cohort of pre-service elementary teachers enrolls in mathematics and science methods courses taught in consecutive hours. (See Mason and Giese [1].) Both professors individually emphasize the importance of the content pedagogy unique to their disciplines. The mathematics methods professor emphasizes strategies such



as teaching problem solving, computation, algebraic thinking, and proportional reasoning in mathematics. The science methods professor emphasizes strategies for teaching students how to "investigate" and "understand" the concepts of science. Both professors want the disciplines they are responsible for, taught as a way of knowing; as a body of knowledge; as interrelated to other disciplines; and as a functioning part of students' everyday worlds.

The mathematics and science methods professors model interdisciplinary instruction by collaboratively teaching common content pedagogy such as the use of technology, data analysis, and interpretation. The concept of simultaneously teaching/reinforcing appropriately selected math and science skills is stressed.

Teaching selected aspects of science and mathematics methods courses in an interdisciplinary way is fully consistent with Virginia's Standards of Learning [2]. In the Virginia's Science Standards of Learning "investigate" is defined as designing and conducting experiments and analyzing the experimental data. For each grade the first science standard defines both the concepts and level of sophistication of experimental design and data analysis to be focused on. Virginia's Mathematics Standards of Learning mandate, "Students also will identify real-life application of the mathematical principles they are learning that can be applied to science..." Both sets of standards specify the teaching of measurement.

Strategies for teaching experimental design include strategies for teaching the components of an experiment, i.e., independent variable (IV), dependent variable (DV), constants (C), control, repeated trials (R), hypothesis, and title. Given scenarios of simple experiments, students then practice identifying each of the listed components in an experimental design diagram and suggesting ways to improve the described experiment. Students are then taught strategies for using different science-related prompts, a general topic, a neat demonstration, an advertisement or a newspaper article, and the Four-Question-Strategy to design an original experiment.

**Four-Question-Strategy**

1. What materials are readily available for conducting experiments on     (Plants)     ?

Soil	Water
Seeds	Light
Fertilizer	Containers
Temperature	Environmental conditions

2. How do     (Plants)     act?

Plants grow.	Plants flower.
Plants fruit.	Plants wilt.
Plants die.	Plants exhibit tropism.

3. How can I change the set of     (Plant)     materials to affect the action?

Soil	Seeds	Water	Container
Composition	Size	Amount	Volume
Amount Color	Frequency	Depth	Color
Color	Age	Application method	Diameter
Depth	#/ container	pH	Location & # holes
Substrate	Mutilation	Type/source	Saucer
Compaction	Treatment	Additives	Cover
Substitutes	Depth	Substitutes	
Critters Specie(s)	Temperature	Material	
Layers or homogenous	Brand/variety	Time of day	
	Mix		
	Orientation		

(Lists for Light, Fertilizer, Temperature, and Environmental conditions)

**4. How can I measure or describe the response of       (Plants)       to the change?**

Measure height. Record color. Count blossoms. Calculate growth rate. Assess health.  
Measure stem diameter. Calculate germination rate. Measure root development.

To complete an Experimental Design Diagram for an experiment, from Question 3, one response is selected as the independent variable and single values are assigned to each of the other responses as they become the constants in the experiment. From Question 2, the action selected is the dependent variable and from Question 4, a means of measuring or describing any changes in the dependent variable is selected. Now the student has only to select the values of the independent variable to test, determine a control, how many repeated trials are needed, and write a title and an hypothesis. At this point an initial draft of his/her experimental design is complete.

**Experimental Design Diagram**

**Title:** The Effect of the Number of Seeds Planted in a Container on the Average Height of the Plants in the Container

**Hypothesis:** If the number of seeds planted in a container is increased then the average height of the plants will decrease.

IV: The Number of seeds per container				← Independent variable
2	4 (control)	8	1	← Level of IV including control
4	4	4	4	← Number of Repeated Trials
DV: Average height of plants in the container (cm)				← Dependent Variable
C: (All responses in Question 3 except IV) water, seeds, fertilizer, containers, etc.				← Constants

It is at this point that the mathematics and science methods classes (same students) are taught jointly to practice using and to extend their knowledge of the quantitative skills that are part of the domains of mathematics, technology, and science are pertinent. Their knowledge

of the applications of computers, basic spreadsheets, and basic graphing software packages is enhanced.

The class reviews the draft of the experimental design diagram to determine if the most appropriate measurement tools, units, relationships, and skills have been identified and used appropriately. A data table is constructed and data properly recorded, graphed, and analyzed using the technology and descriptive and/or inferential statistics which are developmentally appropriate for the students to be taught. Given this approach our pre-service teachers are not left with either the notion that mathematics is the handmaid of science nor is it the queen of the sciences, but rather a co-equal partner. ■

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## **EDIS 788 MATHEMATICS/SCIENCE/EDUCATION FIELD PROJECT AS A CAPSTONE EXPERIENCE IN FIVE YEAR BA/MT TEACHER EDUCATION PROGRAM**

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As a culminating experience, students in the Elementary Education Program Area at the University of Virginia are expected to engage in a field project/thesis experience in the final semester of their program of study. This session will provide an overview of the Field Project/Thesis Experience as it currently exists and will discuss possible variations to encourage more math and science collaborations.

### **An Overview of The Current Capstone Experience**

In the Five Year BA/MT Teacher Education Program at the University of Virginia, the Elementary Education Program Area students are expected to engage in a culminating activity in the final semester of their program of study. The Field Project/Thesis requirement that is included in the Five-Year Teacher Education program is a means by which students in the Elementary Education Program can demonstrate their ability to: identify a problem or issue that is worthy of in-depth exploration, develop a plan or means by which the problem or issue can be studied, engage in those necessary activities to fully explore the problem or issue, report on the results of the exploration and study of the problem, and offer a solution or alternative solutions to the problem or issue.

At the present time, students in the Elementary Education Program Area have been given several options with respect to the means by which they fulfill the Field Project/Thesis requirement. Students may: engage in an investigation of a self-selected topic/area of research, choose a technology oriented project that will be related to some aspect of instructional technologies and classroom implementation issues, or engage in a case-based course (CaseNET) focused on issues of interdisciplinary teaching and internet technologies.

Students in the Elementary Education Program typically engaged in an investigation of a self-selected topic/area of research. Working either alone or with a partner on a topic/area

of investigation, students identify a classroom teacher or teachers with whom they have worked in the past to serve as a resource and project guide. Each classroom teacher provides, where necessary, access to a classroom or classrooms or perhaps even to a school or number of schools depending upon the project's requirements to provide students with the opportunities needed to complete the investigation. The individual student or team, with the assistance of the classroom teacher and a university supervisor designs, implements, evaluates, and reports on the project. Each student or team is required to complete a written report (thesis paper) that may be submitted to the ERIC Document Service on the individual or team's behalf.

A number of students select a technology related project and enroll in an Instructional Computing class, in conjunction with their field project class, that will provide the technical background and support to enable the student to design, implement, and evaluate a project related to some aspect of instructional technology. Students engaged in the technology infusion project typically work within schools and classrooms seeking assistance with technology. Elementary Education students have completed projects related to such topics as techniques for managing a one-computer classroom and a study of the effects of computer location on first graders' usage of computers.

The third option currently available for Curry School of Education Elementary Education students is that of the CaseNET Interdisciplinary Teaching class that is case-based. In this course, all course materials, including readings, reside on the Web. Participants in the course use a variety of Internet technologies. Students connect to other educators across the nation to discuss ways to deal with problems and issues teachers and administrators face on a daily basis. The course is viewed as an opportunity to confront real problems using current technology and as a means by which experiences in the Curry School of Education can be synthesized as a culminating experience.

Since 1991, approximately 100 field projects have been completed and submitted to ERIC by Elementary Education students. Students have completed contracts with classroom teachers and university supervisors that have specified the: project title, problem statement, setting, participants, major goals to be accomplished, steps to be taken to reach the goal, and the project evaluation process.

All projects have been presented along with visuals and related products in the final weeks of the semester. Students at all levels and all faculty in the Elementary Education program are invited to attend the Field Project Presentations and feedback has been provided to the student presenters. In previous years, student presentations have been evaluated using a Likert type scale that has focused on the:

- explanation of the problem or topic
- organization and sequencing of ideas and concepts presented
- evidence of breadth and depth of research on the topic
- use of illustrations and examples to add meaning to major points
- use of audio-visual materials or technology
- explanation of the process of the study
- presentation of the results
- implications or usefulness of the findings or results of the study or project
- overall impression of the project.

Tabulation of feedback sheets has consistently resulted in extremely high percentages of positive reactions to the student projects. Following the project presentations, students are expected to submit a written paper that is read and evaluated by program area faculty and the university supervisor. The evaluation of the written explanation of the field project focuses on such items as:

- general grammatical usage
- explanation of the reasons leading to the choice of project topic or area of investigation
- evidence of depth in the literature review
- rationale and justification for the project
- logical sequencing of the steps of the project
- logical sequencing of the components of the report
- use of available resources
- evidence of coordination of resources in the completion of the project
- depth of discussion of the problem
- explanation of differences between contract plan and final project
- objective reporting of the findings
- acknowledgment of possible competing explanations for the results



- implications and suggestions for future study.

All written papers are evaluated as well in terms of suitability for submission to the ERIC Document Service. Such items as the use of tables, charts, and other attachments and overall conformation to an American Psychological Association (APA) style format are also taken into consideration as papers are considered for submission to ERIC.

### **Future Plans for Math/Science Capstone Experience**

In the newly revised PreK-6 Elementary Education Program at the University of Virginia, the final capstone experience will be expanded to include a fourth option. Students will be given the opportunity to engage in a Mathematics/Science Capstone Experience that parallels the capstone experience in the College of Arts & Sciences. While the details of this particular course are still being developed, the Elementary Education Program area will make available to all its students the opportunity to engage in a team activity that is focused on the investigation and exploration of a math/science related issue in education. Working collaboratively with the Arts and Science faculty who have offered the Life, Physical, Earth and Space science courses and the Geometry and Measurement, Numbers and Number Systems, and the Data and Chance classes, the Curry School of Education faculty will structure a final capstone experience that will be focused on mathematics and science issues as they relate to education exclusively on the design, exploration, and investigation of a math/science related issue.

The capstone experience for Elementary students in the College of Arts & Sciences consists of a two semester experience. Students will work in teams of four or five and complete a mini-project during the first semester. Working collaboratively, the students will explore such issues as forensic science, global positioning systems, sound, modeling, and perhaps some aspect of the material sciences. This mini-project will enable both A & S and Curry faculty to evaluate the students' mathematics and science knowledge, skills, and abilities.

The second semester of the Arts & Sciences capstone experience will be focused on the development of a specific research project in mathematics and science. If the mathematics/science option is selected in the Curry capstone course, a research project related

to mathematics and science is to be conducted with children. This particular experience will be consistent with and conform to the particulars of the existing field project/thesis experience that have been outlined thus far.

It is within the context of this second semester experience that the students will act as researchers and engage in action oriented research at the classroom level and report on their findings. All Elementary Education students in the Curry School who have participated in this experience will have then demonstrated their own classroom research skills within a math and science context. With completion of the two research projects, one - where students perform scientific research, and the other - where students perform educational research focused upon math and science content, students will have a better understanding of the nature of science, and the nature of science teaching.

To date, Elementary Education students in the Curry School of Education have completed Field Projects related to Mathematics and Science topics such as:

- a study of multiple choice vs performance science assessments for second grade students
- the impact of cooperative learning on student attitudes toward math
- a study of the effectiveness and comprehensiveness of a school mathematics program
- at-risk students' attitudes towards science
- the effect of relaxation and visualization on information retention in fifth grade students in science classes.

The new two semester Arts & Sciences math and science capstone experience, and the parallel project added as option four in the Curry capstone, should result in a number of interesting and stimulating math and science focused field projects.

## **In Conclusion**

Given the fact that the Five-Year BA/MT Teacher Education Program at the University of Virginia for Elementary Education students has an already established field project component as a final culminating experience, the inclusion of a Math/Science/Education Capstone Experience will be relatively easy to accomplish. There already exists a functioning capstone experience in the Curry School that can now be expanded to include a clear focus on math and science related issues. With the offering of college courses in mathematics and

science designed specifically for Elementary Education students and the capstone experience offered in the College of Arts & Sciences, the education/math/science capstone experience will be a natural outgrowth of that general studies background and be a significant component in the final semester of the program. Not only will our Elementary Education students have experienced action research within the elementary classroom, they will have demonstrated their ability to be competent classroom researchers as well as competent and knowledgeable classroom teachers. ■

# INNOVATIVE OPPORTUNITIES FOR ELEMENTARY AND MIDDLE SCHOOL TEACHERS TO MAINTAIN CURRENCY IN MATHEMATICS AND SCIENCE: A COMMUNITY COLLEGE-SCHOOL SYSTEM PARTNERSHIP

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Since 1992 the Manassas Campus of Northern Virginia Community College – in response to requests from local school systems – has developed four innovative methods of assisting elementary, secondary and middle school teachers to enhance their **content knowledge** in science and mathematics, as well as **integrate** curriculum units for classroom presentation.

These methods are based on the assumptions that:

- While teachers at this level have fundamental understanding of math and science, if they wish to incorporate new concepts or technologies from these fields, graduate level content courses are generally beyond their background level.
- Community College faculty can often provide a bridge that connects advanced content in science and mathematics with the applications that can be adapted to elementary/middle school curriculum.
- Presenting content to a mixed audience of teachers from K-8 allows teachers to see how content can be "adapted" to grade levels above and below.
- Content delivery methods must be interactive and must be responsive to the multiple demands on these teachers' time. This requires flexibility in scheduling and course requirements.

In the 1991 *Professional Standards for Teaching Mathematics* [1], the National Council of Teachers of Mathematics (NCTM) asserts two fundamental assumptions:

- Teachers are the key to changing the way in which mathematics is taught and learned.
- Teachers must have long-term support and adequate resources.

Under the Standards for the Support and Development of Mathematics Teachers and Teaching, the third standard, relating to the responsibilities of colleges and universities, notes that these institutions must take an active role in supporting mathematics and mathematics education by encouraging faculty to:

- spend time in schools working with teachers and students;
- collaborate with schools and teachers in the design of pre-service and continuing education programs;

- offer appropriate graduate courses and programs for experienced teachers of mathematics.

Although the role of the Community College was not specified in this document, since 1992, Northern Virginia Community College – Manassas Campus has responded to local school systems’ needs by developing four instructional models for implementing these Standards. The focus of the school systems and the community college has been on developing innovative methods for assisting elementary, middle and secondary school teachers who wish to enhance their **content knowledge in science and mathematics**, as well as to **integrate** curriculum units for classroom presentation. In addition to gaining expertise in new content areas and using emerging technologies, faculty members have expanded their own critical thinking skills and have learned to design instructional units that develop critical thinking skills. For both the teachers and their students, planned activities leading to critical thinking in mathematics and science enhances the understanding of these subject areas, reduces the amount of rote memory and helps build those connections which enable *transfer* to occur. Both teachers and students learn the art of reasoning and problem solving.

The instructional models developed by the community college and the school systems are based on the following assumptions:

- While teachers in K-8 have a *fundamental* understanding of mathematics and science, when they wish to incorporate new concepts or technologies, graduate level content courses are generally beyond their background level.
- Community college faculty can often provide a bridge that connects advanced content in science and mathematics with the applications that can be adapted to elementary/middle school curriculum.
- Presenting content along with instructional methodologies to a mixed audience of teachers from K-8 allows teachers to see how content and teaching techniques can be “adapted” to grade levels above and below that which they teach.
- Content delivery methods must be interactive and must be responsive to the multiple demands on these teachers’ time. This requires flexibility in scheduling and course requirements that both lead to understanding of content *and* relate to classroom instruction.

*DISTANCE EDUCATION*

**Math Connects: Patterns, Function and Algebra** is taught via satellite to teachers across the state and presents an exploration of these strands of the Virginia Standards of Learning to middle school mathematics teachers. Topics are explored through an inductive reasoning approach that leads to a specific mathematical function. Topics include:

- Pattern recognition, functions, and graphing
- Independent and dependent variables, interpretations of graphs
- Probability, expected value, and linear functions
- Ratio and proportion
  1. Slope and equivalent fractions
  2. Slope, steepness, similarity, and the tangent function
  3. Use of proportion in a capture-recapture simulation
- Patterns and exponents
- Patterns with geometry and matrices
- Data collection and analysis
- Perimeter and area functions involving maximum and minimum values on an interval
- Binomials: Pascal's triangle, Zero-product property and algebra tiles
- Sets, logic and combinatorial circuits

Lessons use the Virginia Standards of Learning strand *Patterns, Functions and Algebra* for grades 6-8 and Algebra. Most lessons utilize a graphing calculator and a spreadsheet.

**MTH 150 Topics in Geometry** is available on any VCCS campus by compressed video and was designed to meet the needs of students in the Aviation curriculum and for students working towards initial certification in elementary and secondary mathematics. The course is built around the concept and use of vectors. This gives a dynamic aspect to a normally static course in plane, elliptic and trigonometric geometry, and allows for a myriad of applications that can be used in the field of aviation or taken to the secondary classroom as a practical application of geometry. This course will be a world-wide-web course beginning fall 1999.

*CONTENT INTEGRATION*

**MTH 295 Special Topics in Mathematics: Integration and Application of Mathematics** has been designed to focus on the integration of mathematical concepts which

are presented in Pre-algebra, Algebra 1, Geometry and Personal Finance courses. Using materials from many sources, teachers develop a resource bank of applications and problems appropriate to all grade levels. These applications show how principles of mathematics are used in many discipline areas and how mathematics itself is an integrated discipline. Through the use of manipulatives, technology, and writing exercises, the following NCTM strands are emphasized:

MATHEMATICS AS PROBLEM SOLVING

MATHEMATICS AS COMMUNICATION

MATHEMATICS AS REASONING

MATHEMATICAL CONNECTIONS

**NAS 295 Special Topics in Natural Science: Integrated Mathematics and Science K-8** has been designed to reinforce concepts and experimental techniques commonly used in mathematics and science, through hands-on experiences. Two 2-credit, sequential courses are offered during the summer in support of the **AIMS (Activities for Integrating Mathematics and Science) Program** [2]. Through critical thinking exercises, teachers learn the mathematics and science concepts that are the foundation for this activities-centered program. Teachers learn to construct activities that relate the two disciplines using the scientific method and critical analysis. Problems are presented to students, the central question for investigation (purpose) is defined, and variables are identified. An experiment is designed, measurements are taken, and the data generated is organized and analyzed. Conclusions are drawn, implications considered, and results are presented.

### *TOPICAL FOCUSES*

While teachers are comfortable with instructional techniques and topics traditionally taught in grades K-8, many are unfamiliar with topical strands that are contained in the NCTM *Curriculum and Evaluation Standards for School Mathematics* [3]. This is particularly true for teachers of the primary grades. For many teachers, the many demands made on their time and their own limited knowledge of mathematics makes taking a math courses a task they wish to avoid. To overcome this problem, a series of courses has been developed for teachers in grades K-6. These courses are taught for one MTH credit each and are offered on two consecutive Friday evening/Saturday combinations. Topics covered include:

- Data Analysis and Probability
- Number Theory and Algorithms
- Transformational and Coordinate Geometry

In these courses, teachers not only investigate mathematical concepts using manipulatives, but they also learn to adapt these concepts to their own grade level. They learn to construct activities that excite and challenge students as well as enhance critical thinking and problem-solving skills. By working in multi-grade level teams, they see how content strands extend from K-6.

### *SOCRATIC TEACHING*

The NCTM *Curriculum and Evaluation Standards for School Mathematics* stress the expansion of topics taught at the elementary level as well as revision of instructional practices. This revision includes the increased attention to **Questioning** and **Justification of Thinking**.

Several schools within the region have implemented the Comprehensive School Mathematics Program (CSMP), published by the Mid-continent Regional Educational Laboratory (McRel) as an alternative to the standard mathematics curricula. This program emphasizes the expansion of basic skills to include higher-order thinking skills. It is a unified study of mathematics, not just arithmetic, and its approach is situational discovery learning presented in a spiral format. Central to CSMP is the methodology of Socratic Teaching. While elementary teachers employ the Socratic Method in their language arts classes, those unsure of their own subject area competency are more comfortable with a do-as-I-show-you approach to mathematics. They need to be convinced that questioning, in addition to showing and telling, enhances in mathematics and science instruction. See, for example, [4], [5], [6].

In preparing teachers for teaching the CSMP program, a unique in-service model has been developed. Groups of teachers are given a 2-3 day introduction to the philosophy, content and methodologies used by CSMP. The teachers review the materials and then, as a group, are freed to observe the trainer delivering model lessons to students at several grade levels. At the end of the day, participating teachers convene to discuss their observations. This cycle is repeated several times before the teachers begin using the materials in the classroom. As the year progresses, the trainer meets with the teachers, the trainer observes classes and the



groups meet to assess the program and plan for further implementation. This monitoring insures that adequate support is provided throughout the year, and other teachers have the opportunity to observe the interactions and adapt these techniques to their own teaching.

### CONCLUSION

By showing these four models we have demonstrated that the community college can provide resources which meet the needs of school systems for in-service education, enhance teachers depth and breadth of content understanding, and facilitate the development of instructional techniques that reinforce critical thinking and understanding. ■

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# **CURRICULUM RESTRUCTURING AT LYNCHBURG COLLEGE: EFFECTS OF REALIGNMENT TO STATE-MANDATED COMPETENCIES AND IMPLICATIONS FOR K-6 MATH AND SCIENCE TEACHER PREPARATION**

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Because Lynchburg College offers a four-year program to attain teacher licensure, current restructuring efforts have been aimed at targeting the professional studies requirements across a program of courses that are efficiently integrated. Math and science methods courses will be combined into a workshop course. A new general studies program has been approved which requires eight hours of lab sciences and three hours of math. A General Science course has been approved which will be geared towards pre-service teachers. The professional core requires an additional eight hours of lab sciences, totaling 16 hours in science, and six hours of math, geared towards the needs of pre-service teachers. While recommended teaching practices are stressed, these may be de-emphasized by the student teaching capstone experience. This is due to the current pressure in public schools to address content-loaded Standards of Learning. From this perspective, standards-based education may prove to be an impediment to reform efforts in science education that stress process skills and the messy, time-consuming nature of learning.

This presentation will summarize curriculum restructuring efforts at Lynchburg College with respect to their effect on pre-service K-6 teachers' math and science preparation and address some potentially negative impacts of the standards-based movement on teacher preparation. A new general education program has been approved and efforts are currently underway to restructure and align the professional studies programs with the Virginia Department of Education Program Status Matrix. These new programs potentially increase the exposure of K-6 pre-service teachers to math and science course work, which will better prepare them to teach.

Lynchburg College, by virtue of its small size and the relatively large percentage of its graduates in Education, offers some promising possibilities for collaboration between science, math, and education departments. Pre-service teachers comprise more than 30% of students enrolled in introductory math and science courses. Through such collaboration, faculty in the science and math departments have designed courses that cater to the content needs of teacher preparation students. These include a two-semester sequence called General Science (with

labs), which focuses on some of the major science principles [1]. A two-semester math sequence has also been designed to accommodate the needs of pre-service elementary teachers (Introduction to School Mathematics I & II). Course objectives include an emphasis on NCTM standards and the formulation of lesson plans. Other encouraging interdisciplinary efforts included a science curriculum unit approved as part of the requirements in an environmental science course for prospective teachers enrolled in that course. Such collaborative efforts are made possible through open communication in smaller institutions where faculty regularly see each other.

A major outcome of the new general studies program was to reduce the number of hours required so students can have more elective courses. With only one mathematics and two lab-science courses required for general studies, the major interdisciplinary component was expanded to include eight additional hours of science and six hours of math, with science courses mentioned above strongly recommended and the “school math” sequence required. This totals 16 hours in lab-based science courses and nine hours in math courses. Current restructuring of the teacher preparation programs poses some complex problems because the state endorsement competencies must be addressed in a four-year program. As part of the realignment process, the education faculty is actively seeking to collaborate with other departments to assure that content specific competencies are being addressed. Such an integrated approach not only assures that the College meets state competencies, but may also positively influence student attitudes about the usefulness of their coursework.

The Program Status Matrix for Elementary Education PreK-6 delineates a fairly well defined set of content standards (Virginia Standards of Learning for elementary level) and alludes to the nature of science and math and its relatedness to technology. It also alludes to the ability to effectively teach content, skills, and principles. In contrast, the matrix for *Professional Studies Requirements, Elementary Education PreK-6* lists five major competencies with no specific mention of math or science—only “...the application of skills in discipline-specific methodology”, under “2. Curriculum and instructional procedures”! To accommodate the many other competencies to be addressed under these major groups, plans have been made to combine the two separate two-hour math and science methods courses into a single three-hour workshop type course.

If implemented as outlined, beginning in fall 1999, Lynchburg College K-6 pre-service teachers will receive a total of 16 hours in science content, nine hours in math content, and three hours of math/science teaching methods coursework. This preparation is transformed into practice through a sequence of three one-hour field experience courses (observation, individual tutoring, and single lesson whole-class instruction). Finally, the capstone student teaching experience requires a minimum of 300 contact hours and earns 12 hours credit. This gradual transition into apprenticeship is critical with respect to transforming theory into practice and can have a strong influence in shaping future teaching. The possibility of pre-service and inexperienced teachers being influenced by established teachers modeling behaviors not in line with current reform efforts continues to be a concern for teacher educators. Currently, this situation has been exacerbated by implementation of the Standards of Learning. Two issues are addressed below.

The Virginia Standards of Learning for science begin with a set of general goals that mesh nicely with the scientific “habits of mind” [2]. The first SOL cluster for each grade level is entitled “Scientific Investigation, Reasoning, and Logic” and includes a listing of these skills and practices. These are followed by 7-14 other major groupings of standards primarily referring to science content. These content standards are well in line with national standards [3]. For example, light, heat, electricity, and magnetism are listed as K-4 standards in the National Standards and these same topics are listed in the Virginia Standards for the K-4 level (light is listed as a 5<sup>th</sup> grade SOL). Though process is taught in the context of content, the listing of the SOL in this manner may encourage teachers to focus more on fact-based, direct instructional methods.

With pressure to improve SOL test scores, there may be a tendency for the teacher to attempt to “cover” all the SOLs as fact-based knowledge instead of an inquiry-based approach. In this respect, the credo of “less is more” [4] is traded for “If I don’t cover all these SOLs, the blame will rest on my shoulders!” Two very interesting outcomes from this perceived pressure are already impacting the pre-service teacher program at Lynchburg College. Some schools are now begging for more field experience students to tutor some of their children who have a low probability of passing the SOL tests. On the other hand, many schools do *not* want as many student teachers because the amount of mentoring required by the supervising teacher and the time the student teacher takes learning to teach effectively

detract from the time available to “cover” the SOLs. It should be noted that while there are negative effects due to implementing the standards, in many cases they have forced teachers to devote more time to math and science instruction and have given structure to teachers who might flounder otherwise.

Plans for improved pre-service teacher preparation at Lynchburg College are encouraging. An improved general education program that effectively addresses the needs of pre-service teachers, combined with methodology coursework and practicum experience, will hopefully result in an effective teacher preparation program. Whether current pressures placed on the teaching environment by the standards movement discourages recommended practices remains to be seen. The period of adjustment in the coming few years will offer plenty of challenges. ■

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- [2] J. F. Rutherford and A. Ahlgren, *Science for All Americans*, Oxford University Press, New York, 1989.
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# WONDERS OF TECHNOLOGY – TEACHING PHYSICS TO NON-SCIENTISTS<sup>1</sup>

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*Wonders of Technology* is a conceptual physics course developed for non-science majors. The approach taken here in the introduction of the physical concepts is to depict their role in today's technology, specifically the technology familiar to the students, and also to emphasize the connection between technology, art, and culture from the historical perspective.

Why this approach? The traditional method of teaching physics is perceived by many students as “user-unfriendly” – they think physics is difficult, abstract, and, in fact, of little or no relevance to everyday life. The course *Wonders of Technology* alleviates this perception by placing the students on familiar ground that provides a fertile environment for an easier assimilation of knowledge. By examining the technology students use on a daily basis to demonstrate how physics makes things work, students are motivated to seek understanding of the principles underlying their operation. The course was developed within the guidelines of the new general education requirements at Virginia Commonwealth University.

This presentation highlights some of the highly successful features of the newly developed course, with emphasis on responses from the education majors who are enrolled in the course.

## Features of the Course

*Wonders of Technology* is a one-semester course. The course features:

- Multidisciplinary approach,
- Emphasis on technological and real life applications,
- Exercises to enhance critical objective thinking, and design flexibility to allow for vertical curricular integration,
- Unit format that stresses a project / laboratory / hands-on approach,
- Multimedia, highly interactive, and Web-based course presentation.

The text emphasizes the process of socializing scientific information and teaching students how to obtain additional information for life-long learning. Students achieve science literacy

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<sup>1</sup>The development of the course is sponsored in part by the NSF-funded Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT).

by studying the processes, concepts, and significant details of modern experimental science and technology. They are required to apply the material learned in class to everyday applications. Activities and tests encourage development of the mental skills necessary to think scientifically and understand and respond critically to science articles and programs in the popular media. These activities and tests also give the students some understanding of the relationships of science to religion, ethics, politics, economics, and the arts. The unit format stresses project/laboratory/hands-on components, with high student involvement.

The *lecture component* is multimedia and interactive. During this period the students are introduced to topics from life-related experiences, using films, demos, simulations, etc. The topics are (in the order they are listed):

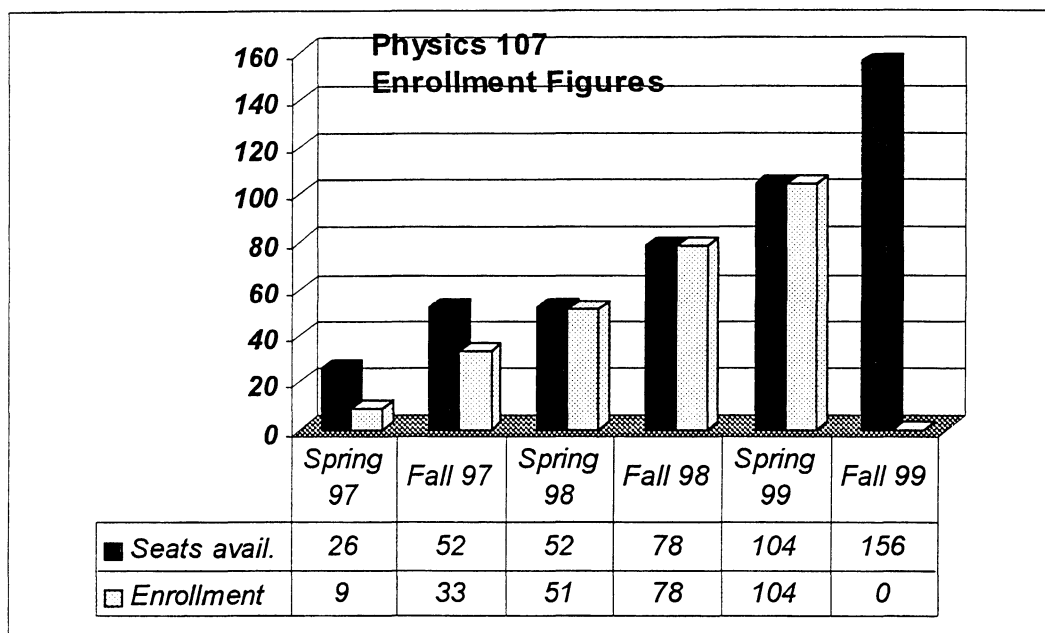
- Balance, Benefit and Doubt (dealing with the science of measurements)
- The Nature of Things (structure of materials from macro to micro)
- The World of Light and Color (develops the laws of optics)
- Bridges over Space and Time (electricity and magnetism)
- The Ultimate Ride (mechanics)
- The Future is Here (latest breakthroughs in physics and technology)

During *the lab*, the students work on projects that have relevance to the problems raised during the lecture presentations. Cookbook quantitative labs are avoided, conversation is encouraged, and speculation is rewarded. At the conclusion of the hands-on project, a *general discussion* of the topic, with its relevance to personal life, technology, and other sciences, follows. The discussions focus on the interdisciplinary nature of the phenomena. Interactive-computer programs are used where appropriate.

### **Preliminary evaluation and assessment**

The course was first offered on an experimental basis in spring 1997. From this tentative start the course enrollment has grown steadily; the number of sections increased to 2 (sections are limited to a maximum number of 26 students), then three, then four and it is anticipated that six sections will be offered this coming fall.

This growth is shown in Figure 1, opposite, and apart from the first two semesters, enrollment in each section has been full well before the registration deadline.



**Figure 1. Enrollment in *Wonders of Technology*.**

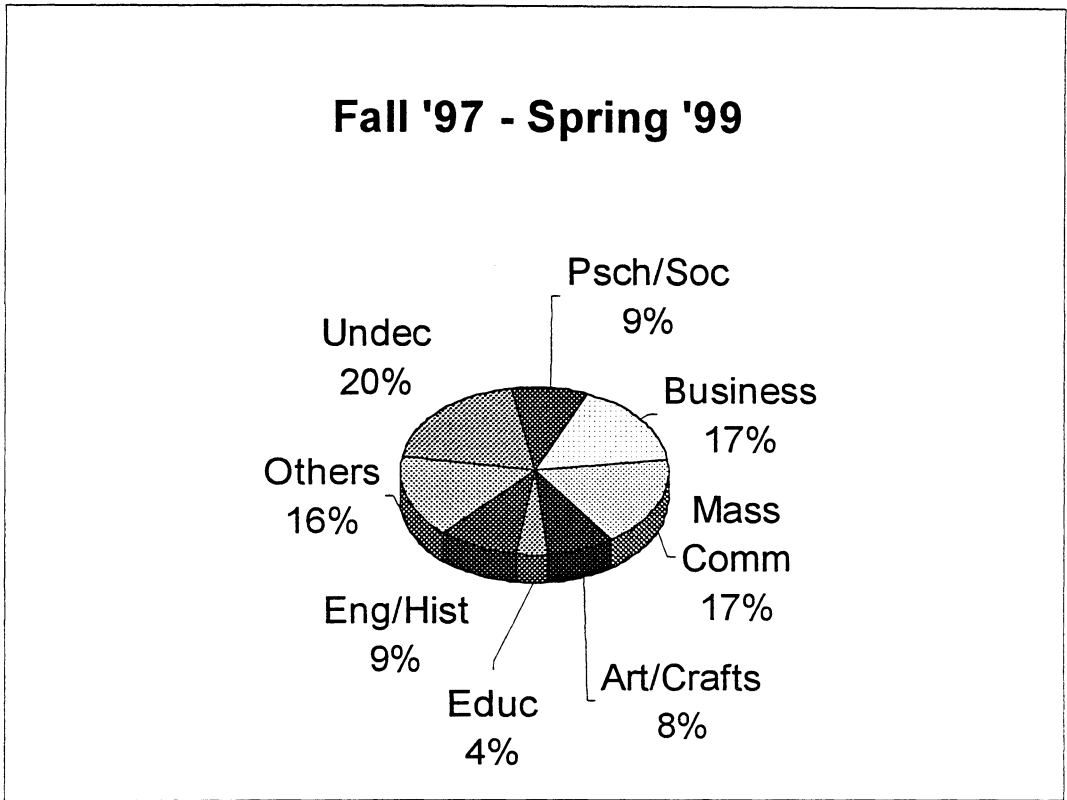
The size limit of 26 for the classroom is used for both lectures and laboratory projects. By keeping the section size low each student receives individual attention and by necessity must contribute to the projects.

Student evaluation is made through project reports, practical exams, quizzes and homework. The final exam is given as projects that, to the extent possible, are pertinent to the students' major.

The composition of the sections has been monitored carefully for the last four semesters. The male/female ratio has remained very close to 50% from the start. Mass Communications and Business are the most common declared majors and the low percentage of Education majors is a bit of a surprise as it can be seen in Figure 2 on the following page.

Comments made by education majors in the evaluation of instruction have been very favorable, indicating that the content and methodology of the course would be of direct benefit to their major.





**Figure 2.** Majors of students enrolled in *Wonders of Technology*.

In the fall of 1998 VCEPT conducted a survey of student assessment of VCEPT courses. A total of 23 students enrolled in *Wonders of Technology* responded, and their reaction is summarized in Figure 3, opposite.

From their answers we feel that to a large extent the goals and objectives have been met. Moreover, an assessment questionnaire given in the spring of 1998 by the committee for implementation of the general education requirements within the College of Humanities and Sciences at VCU, revealed the fact that the students who took *Wonders of Technology* in conjunction with the introductory biology course, performed as well if not better than all the other natural science/physical science sequences. ■

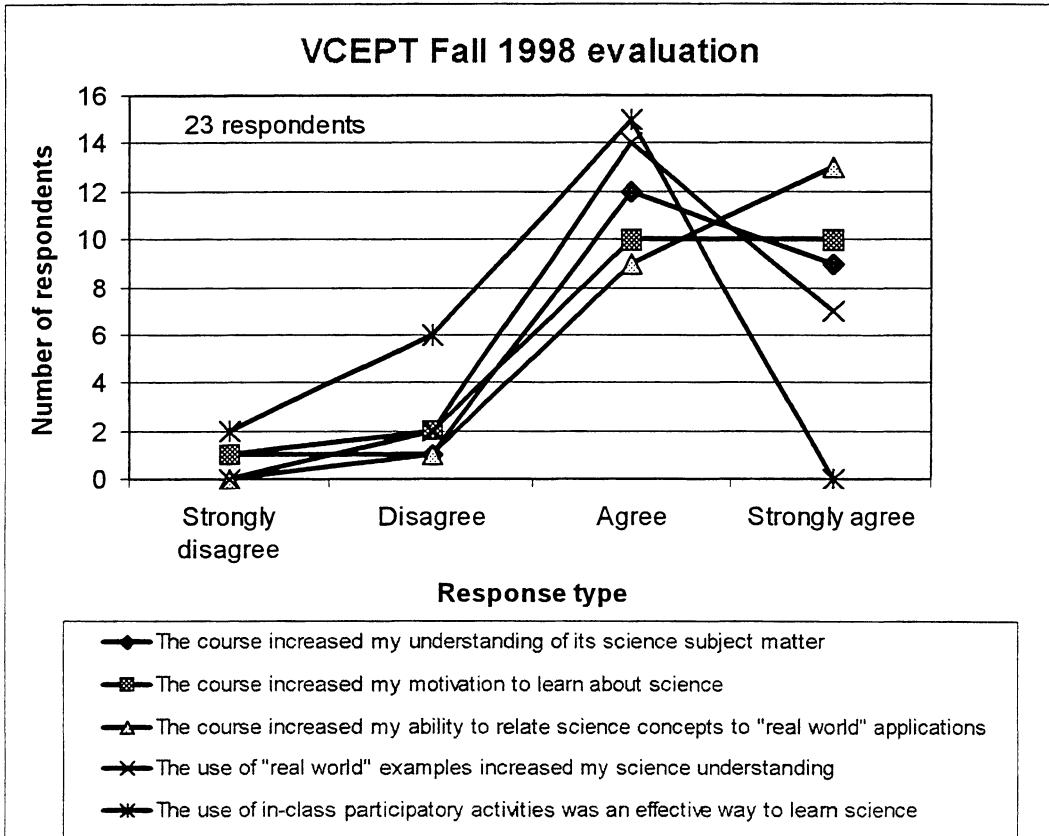


Figure 3. Student assessment of *Wonders of Technology*.



## ***EXPERIENCING SCIENCE, AN INTRODUCTION TO “REAL” METHODS OF SCIENCE FOR THE PRESERVICE TEACHER***

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The “scientific method” presented in the middle school classroom introduces the experimental approach of science in a way that may actually bear little resemblance to the processes actually used by working scientists. Teachers equipped with an insight into the motivations, philosophy, tools, and culture of science will better convey an accurate and positive picture of science as a critically important human endeavor. The *Experiencing Science* course was designed to answer the challenge of giving the pre-service teacher and decision-maker better insight into actual processes used by scientists, in the context of each of the major disciplines.

*Experiencing Science* (VCU INSC 300), a 3 credit hour course, was developed by a Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) team from Virginia Commonwealth University, Mary Washington College, J. Sargeant Reynolds Community College, Longwood College and the Science Museum of Virginia. Support for development of *Experiencing Science* was provided by VCEPT and the Science Museum of Virginia’s Center for Science Education. VCEPT is a National Science Foundation supported collaborative consisting of nine Virginia colleges and universities, the Mathematics and Science Center, and the Science Museum of Virginia. The Science Museum of Virginia is a state agency and an educational institution with a twenty year history of interpreting the principles of science. The Museum has a Digistar planetarium and over 200 interactive exhibits in nine galleries interpreting science concepts including: Optics, Acoustics, Force and Motion, Astronomy, Chemistry, Crystals, Telecommunications, Aerospace, and Electricity and Energy.

A team of four faculty members from three institutions has taught the course, with a representation from the physical sciences, life sciences and earth sciences. An important part of the revision of the course in the current term involves placing greater emphasis on the mathematical tools used by scientists in modeling, analyzing, and describing natural phenomena. Statistics, graphical presentation of data, and the power of math modeling are

components of the course in the present semester.

The premise for the development of this course is that the “scientific method” as presented in the middle school classroom introduces the experimental approach of science in a way that is inaccurate at best, and may actually bear little resemblance to the real processes used by working scientists. Imagine for a moment the notion that for every individual scientist in daily work a new hypothesis leads daily to a new theory. As Bauer states in the course text, *Science and Its Ways of Knowing* [1], teachers equipped with an insight into the motivations, philosophy, tools, and culture of real working scientists will better convey an accurate and positive picture of science as a critically important human endeavor. The *Experiencing Science* course was designed to answer the challenge of giving the pre-service teacher and community decision-maker a better insight into actual processes used by scientists, in the context of the each of the major disciplines.

In the Summer 1997 and Spring 1998 the course was offered as a 200 level course with a PHY (physics) designation. It met at the Science Museum of Virginia, using its resources and interactive exhibits, with field trips and class meetings at other sites, designed to take advantage of the many research opportunities in science available near the Virginia Commonwealth University (VCU) campus. Semester projects, experimental investigations, readings from original science works, and an exam are part of the course structure. In order to present a unifying theme for a context of the three main disciplines, energy is taken as the central concept. Energy is seen in the physical sciences, (potential and kinetic; chemical and electrical, etc), the life sciences, (the cell as an energy transducer, the trophic pyramid and the food web), and in the earth sciences (weather, tides, orbits), providing a thread to unite the widely disparate science themes visited in the course of a semester.

In Spring 1999 the course is offered as INSC 300 (Interdisciplinary Science designation), open to all students, with the newly added prerequisites of one General Education course each in mathematics and science. This change was intended to give the student a more effective set of tools to see examples of science at work. The first two semesters revealed that a level of understanding in biology and physics, as well as some facility with mathematics is required to grasp the key elements of the course. This modification has served the course well, as the current Spring 1999 semester is composed of future teachers with a much stronger

background in several sciences and in mathematics.

As modern science is increasingly a distributed process, communication is a critical and functional element. The essential aspects of collaboration and competition in the working science disciplines are modeled in the class and in the research projects. The all-important recognition and communication of science research, the peer-reviewed paper, becomes in this course an introduction to science as it is practiced. Students conduct research projects in teams and present their work in regularly scheduled symposiums during class time, with class participation in questions and suggestions of the other research teams. Thus, the communication of science to the immediate community and beyond is introduced in a real-world format. The portrayal of discoveries in the news media is studied and the analysis of this communication is incorporated into course activities. The benefits of collaborative efforts and the productive aspects of competition are studied in readings and experienced in course projects such as a classroom "race" to identify a new species and submit the report of its discovery in an abstract to a journal editor.

The course employs a student journal as a model of the research tool, as a lab notebook, a personal journal, and a means of communication between student and the teaching team. The journal is used for in-depth evaluation, as researcher's diary, and as an assessment tool.

The remarkable differences in approach among the different science disciplines are recognized in the course: the physical sciences and the repeated experiment, the field studies of the life scientist, and the computer model of the astrophysicist. Students investigate the distinct culture of different science disciplines -- a direct result of the nature of the subject matter, which may be data-rich (meteorology or geology) or theory-rich (cosmology).

An important part of the revision of the course in the current term involves placing greater emphasis on the mathematical tools used by scientists in modeling, analyzing, and describing natural phenomena. Statistics, graphical presentation of data, and the power of math modeling become a larger part of the course in the present semester. Students take data in experiments, (the time of falling objects from different heights, for example). They plot the data and use analysis to determine error, confidence based on scatter or variation, and eventually determine the acceleration of gravity.

Another example of mathematics applications is found in the semester-long projects. One project team is attempting to measure the acceleration of Earth's gravity ( $g$ ) at several points in Central Virginia with the greatest accuracy possible, using a pendulum and a stopwatch. They will use statistical methods and error analysis to describe the degree of confidence in their result, with data taken at one location for comparison to a published value. This approach, rather than the use of modern, solid state instruments, challenges the student to be resourceful, to think critically, and to use mathematical tools to the greatest advantage. A second team is determining the size and distance of the moon by measuring apparent angular size without modern instruments. (They will, however, have access to a good photograph of a lunar eclipse for part of the data-gathering). The mathematical tools used in this project will include Euclidean geometry and error analysis. A third project will be the correlation of the "afterimage effect" of color perception in humans as a function of different colors used, with a statistical analysis of results.

Dealing with the question, "What is Science?", is an important aspect of the course. In fact, distinguishing the examples of "pseudo-science" from what is recognized as real science is a recurring theme throughout the semester. The writings of Karl Popper in the course text, *Science and Its Ways of Knowing* [1], are used as an introduction to a delineation of the scope of science. Should scientists study UFO reports, or search for extraterrestrials? A core concept is presented: a proposition which is put forward to the science community to be tested and to be proven false, is a scientific statement, while a deeply felt belief is not a part of science at all. Thus, Creationism, Scientology, and other examples of doctrine-driven cultures are distinguished from science in the course, as they are not open to objective study and testing.

The course offers practice in critical thinking techniques for gaining understanding: recalling and identifying key facts and relationships, applying and combining known information in new applications, and judgment about precision, accuracy, consistency, or effectiveness of information. Different methods of investigation are modeled: observation, classifying, communicating, measuring, predicting, hypothesizing, modeling; inferring from, interpreting, and analyzing data.

Readings from the text introduce ideas of some of the great scientists, giving a more

sophisticated appreciation of science concepts, and benefitting a non-science major in a modern decision-making or teaching career. The course is intended to give future teachers a sense of the importance of science to all of modern life and human endeavor. ■

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## TEACHING PHYSICAL SCIENCE THROUGH TECHNOLOGY: MIDDLE SCHOOL VCU PHY 591

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*Teaching Physical Science through Technology* is a new 3-credit laboratory-and-lecture based course designed to serve as an introduction to the teaching of physical science concepts at the middle school level. Physical science phenomena are presented through investigations of commonly known applications of technology and focus on the Virginia Science Standards of Learning for 6<sup>th</sup> Grade Science and the Physical Science courses. Topics include matter, gravity, mechanics, heat, optics, electricity and magnetism, and computers as seen in their roles in common devices. The development of the course includes assessment from six semesters, collaboration with other institutions including the Science Museum of Virginia, and an 800 page text written by Adam Niculescu.

*Teaching Physical Science through Technology* is a new course sponsored by the NSF-funded Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT). The course development is also a collaboration of the *Gateway 2000* Richmond Public Schools NSF project, a local systemic initiative, the Eisenhower Program for Professional Development through the State Council of Higher Education, and the Science Museum of Virginia's Center for Science Education. In its present form the course was designed in response to a request from Richmond Public Schools for support of middle school teachers preparing to meet the challenge of Virginia's Science Standards of Learning. It is being developed and tested for use by preservice teachers as a 3 credit lecture-and-laboratory-based course.

The original concept for the course evolved from a summer teacher workshop conducted by the authors and funded by Virginia's State Council of Higher Education Eisenhower program. The premise of this workshop, entitled the *Reality-Based Physical Science Teachers' Workshop*, was that physical science could be introduced effectively for teachers and students through examples seen in everyday life, using these familiar physical science applications as a pathway to understanding the underlying phenomena. The technology of

modern civilization, including electrical, magnetic and electronic devices, transportation, computers, household appliances, and materials (including crystals and composites) all hold within them a story to be unfolded through investigation. The important essentials of physical science phenomena then become the focus of the class, and related to the Virginia Science Standards of Learning [1].

This approach avoids the traditional physics presentation: formulas displayed on a blackboard, followed by repeated problem solving, with the laboratory experience treated as a quite separate and isolated process – often with a fill-in-the-blank sequential laboratory worksheet.

Examples of the new approach can be found in the section on materials. Crystals are introduced by a photograph of the Hope Diamond and optical calcite crystals investigated by students before the geometry of the unit cell is introduced. The VCR, computer, aircraft engine, MRI, AM and FM radio, lasers in CD ROMS, light bulbs, concrete, and the pyramids are among the many hundreds of physical examples used to introduce core concepts in physical sciences. The “projects” or laboratory experiences of the course all present investigation of the phenomena in the context of these examples of technology.

All aspects of the physical sciences are treated: electricity and magnetism, mechanics, heat, optics, acoustics, and gravity, by depicting their role in commonly known devices and applications. The approach is specifically designed to equip teachers to meet the sixth and eighth grade (physical science) Virginia Science Standards of Learning, which are correlated to each class lesson.

The course is structured with lecture, experimental projects, and recitation integrated in a laboratory-type setting using the facilities of the Science Museum and the VCU Physics Department. At the museum, students use the interactive exhibit units of electricity and magnetism, the Crystal World, the large Foucault pendulum, the Digistar planetarium and the aerospace wind tunnel units.

The course text and laboratory manual was written by Adam Niculescu for the undergraduate version of this course *Wonders of Technology* (PHY107 at VCU) [2] and

presents the physical sciences in context with human endeavor: art, technology, architecture and engineering. The features of this text are:

- multidisciplinary approach
- emphasis on technological and real life applications
- exercises to enhance critical objective thinking, and design flexibility to allow for vertical curricular integration
- Unit format in this text stresses a project / laboratory / hands-on approach.

The text emphasizes the process of socializing scientific information and teaching students how to obtain additional information for life-long learning. Students are expected to strengthen science literacy by studying the processes, concepts, and significant details of modern experimental science and technology. By applying the material learned in class to every-day applications, science can become an integrated part of a student's grasp of the world around them. Activities and tests encourage development of the mental skills necessary to think scientifically; the ability to understand and respond critically to science articles and programs in the popular media, and give an understanding of the relationships of science to religion, ethics, politics, economics, and the arts. The central themes of the text are:

Balance, benefit and doubt, (the science process);  
The nature of things (matter);  
Symphony of Light and Sound (optics and acoustics);  
Bridges over Space and Time (communications);  
The Ultimate Ride (transportation); and  
The Future is Here (human imagination).

The unit format stresses project/laboratory/hands-on components, with high student involvement.

*Segment I* is a Lecture component with multimedia and interactive participation. During this period students are introduced to topics from life-related experiences, using films, demos, simulations, etc.

*Segment II* is the Laboratory component, with students working on projects that have relevance to the problems raised during Segment I. Cookbook quantitative labs are avoided, conversation is encouraged, and speculation will be rewarded.

*Segment III* is the Development of Enrichment Components (Recitation). At the

conclusion of the hands-on project (lab), a general discussion of the topic, its relevance to personal life, technology, and other sciences follows. The discussions focus on the interdisciplinary nature of the phenomena. Interactive-computer programs are used.

The tests are designed as laboratory projects. The compulsory final exam will be given as projects that are pertinent to the focus of the student. To the extent possible, the homework is an extension of the experiments done in class and is assigned in the form of practical projects.

As part of the laboratory experience for the course, the class will participate in the seven, hour-long, hands-on activities under the Science Museum's leadership at the Mathematics and Science Day at the Paramount Kings Dominion Park. This involves the teachers in preparation for an array of physical science measurements and experiments from hand-held accelerometers to remote measurement techniques.

The class members produce projects as an essential course component. These EXAM-projects are to be presented in the last two class meetings. Instructors assist only with supplies, equipment, and safety issues. The exam-project options are outlined in the text-lab manual and are to be tested in the classroom. There will be 3 EXAM-projects during the semester as shown in the schedule of activities.

The final exam consists of two parts:

- A final project to be designed by the student under the supervision and with the assistance of the instructor, and presented during the finals week.
- A standard exam containing questions from the material covered during the semester, and to be taken at the end of the presentations.

This pilot version of the course at the graduate level was developed specifically for Richmond Public Schools, and is under evaluation for effectiveness as measured by the teachers' success in preparing students for the Virginia Science Standards of Learning tests.

Teachers participating in the course are provided classroom kits covering the science themes investigated, as well as the course text. The course runs on a school division schedule

in Spring 1999 and continues after the summer break for three meetings in which project presentations and exams are held. ■

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## USING TECHNOLOGY AS A VEHICLE TO APPROPRIATELY INTEGRATE MATHEMATICS AND SCIENCE INSTRUCTION FOR THE MIDDLE SCHOOL

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At the College of William and Mary, pre-service middle school science and mathematics teachers enroll in their respective methods courses taught in the same time period. Both instructors emphasize the importance of the content pedagogy unique to their disciplines in their individual courses such as strategies for teaching problem solving, computation, proportional reasoning, algebraic and geometric thinking in mathematics, and strategies for teaching students how to "investigate" or design and conduct experiments in science. However, the two classes come together for sessions in which they examine the relationship of the two disciplines and the proper role of technology, both graphing calculator and computer, in their instruction. Starting with resources such as *Science in Seconds for Kids* by Jean Potter [1], the science students collaborate with the math students to design and conduct brief experiments. The data generated is analyzed using spreadsheets and later graphing calculators. Various classes of mathematical curves are examined using data generated by sensors/probes and CBLs. Through this experience the pre-service teachers learn to work collaboratively with their colleagues on meaningful tasks, strengthening the effectiveness of all participants.

Among the competencies that the new teacher licensure regulations for middle education (6-8) in Virginia prescribe that the teacher candidate demonstrate are:

- 1) the ability to plan and teach collaboratively to facilitate interdisciplinary learning;
- 2) the ability to analyze, evaluate, apply, and conduct quantitative and qualitative research;
- 3) the ability to use technology as a tool for teaching, learning, research, and communication.

In order to accomplish these goals, the mathematics education and science education faculty at the College of William and Mary have redesigned the methods courses for these prospective teachers in both areas. Both instructors, Mason in mathematics education and Giese in science education, emphasize the importance of the content pedagogy unique to their disciplines in their individual courses such as strategies for teaching problem solving,



proportional reasoning, algebraic and geometric thinking in mathematics, and strategies for teaching students how to "investigate" or design and conduct experiments in science. However, the two classes come together for sessions in which they examine the relationship of the two disciplines and the proper role of technology, both graphing calculator and computer, in their instruction.

In their mathematics methods course, students learn strategies to teach four core processes in mathematics: becoming mathematical problem solvers, reasoning mathematically, communicating mathematically, and making mathematical connections within the discipline and to other disciplines. In their science methods course, students learn strategies for teaching experimental design including the components of an experiment. After analyzing the components of several simple experiments and suggesting ways to improve them, students learn strategies for using different science-related prompts, a general topic, a neat demonstration, an advertisement or a newspaper article, and the Four-Question-Strategy to design an original experiment. These skills are then applied to designing and conducting experiments which integrate math and science concepts utilizing technology. Starting with resources such as *Science in Seconds for Kids* by Jean Potter [1], the students collaborate to design and conduct brief experiments. The data generated is analyzed using spreadsheets and later graphing calculators. Various classes of mathematical curves are examined using data generated by sensors/probes and CBLs. Through this experience the pre-service teachers learn to work collaboratively with their colleagues on meaningful tasks, strengthening the effectiveness of all participants.

For example, one such experiment involves testing an inflated basketball. As described in the book *Sensor Sensibility* [2], a basketball which is inflated properly rebounds to 75% of its original height if it is dropped. In this experiment, students drop a basketball underneath a motion detector. The motion detector will record the distance to the ball for a long enough time to collect values for at least five bounces. The students then analyze the data to see whether the ball passes the 75% rebound test and find a mathematical function to describe a bouncing object.

Students identify the independent variable and the dependent variable in this experiment. They then predict the graph of the data, labeling the axes to indicate the independent and

dependent variables. They next guess the type of function that will model any part and justify their choices. Then they perform the experiment using a CBL system, TI-83 graphing calculators, a motion detector, and a basketball. Generally, the students experiment with the measurements they take, varying such things as the time interval and the height from which the ball is dropped. Eventually, once they have settled on a design and collected their data, they analyze it, comparing their graphs to the predicted ones and accounting for the differences. They find a function that fits the graph well and justify that function as a good model. (It is a decaying exponential function.) The numbers in the data table showing the heights of bounces will match a geometric sequence. The ratio between these numbers is more or less constant, and matches the elasticity and inflation of the ball. The height from which students initially drop the ball is the first term in the sequence. If students are familiar with equations of parabolas, they can model a single bounce with a quadratic function.

By working together to design and carry out such experiments, both preservice mathematics and science teachers learn how to collaborate with one another and integrate instruction in these disciplines where appropriate. ■

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## DATA VISUALIZATION TOOLS FOR SCIENCE AND MATH

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As the computers available in schools become more powerful, more and more exciting tools are available to science and math students and teachers. Visualization tools, such as image processing, geographic information systems, modeling, and simulation software, are a class of tools with particular promise. These tools are being used in schools across the country to integrate computer use with the curriculum and to bring more hands-on inquiry to the students. A primary goal of using these computer-based tools is to aid students in developing a deeper understanding of the science and math (not the computers) and to help make difficult concepts a little easier to grasp (and visualize).

In particular, these tools allow students to collect, analyze, and manipulate data, a fundamental requirement of the Virginia Standards of Learning [1]. More importantly, these tools allow students with a variety of different learning styles, especially visual learners, to help make abstract concepts into concrete expressions. Teachers can use the computers as a laboratory to study phenomena they could never fit into their classroom (like remote sensing of Earth to study land use and geology from space).

One of the challenges in bringing these tools to students is how to do the faculty development to bring the tools to teachers. In this session, we'll explore the possibilities that these tools offer, examine the challenges, and try to understand how to prepare future teachers to use these and other tools in their classrooms.

There are two complementary forces at work in the use of educational technology in K-12 classes. There is a push from groups that advocate the use of computers integrated with instruction. Many districts have made substantial investments in hardware and networks only to find the machines being used as little more than glorified typewriters. There is pressure to find ways to make use of the computers as an integral part of the learning process rather than as an add-on. There is also a pull from the curriculum and from content groups that focus on the opportunities that computers offer to bring new learning opportunities and to address students with different learning modalities. The pace of change in science content has drastically changed the make-up of current secondary science classes (compare a current high school biology class to what was offered a generation ago) and introduced opportunities for curricular content that can most easily be facilitated with computers. We highlight some of the curriculum connections below in Table 1.

Visualization Tool	Subject Area	Grade Level	Content Connection/Description
Image Processing	Biology	9-10	Mitosis: Microscopic movie of a cell undergoing mitosis. Students discern the different stages and develop a model for the process.
Image Processing	Earth Science	9-12	Global Climate: Time-lapse sequence of the Antarctic ice pack. Students measure the size of the ice pack as a function of month and year and compare measurements.
Image Processing	Physics	10-12	2-D Motion: Movie of a person shooting a free throw. Students measure the motion of the ball and use the trajectory to calculate $g$ .
Image Processing	Biology	7-8	Homologous Structures: Images of x-rays of different animal forelimbs. Students identify the animal and compare and contrast structure.
GIS	Earth Science	9-10	Natural Resources: Students map the location of different natural resources and identify their geologic origins.
GIS	Earth Science	10-12	Plate Tectonics: Mapping of earthquakes and volcanoes. Students explore the location of volcanoes and earthquakes and compare their location to plate boundaries.
GIS	Ecology	10-12	Population Dynamics: Students map the location and growth rates of humans and other species and compare with available resources.
Molecular Modeling	Chemistry	11-12	Molecular Structure: Students explore the three-dimensional structure of molecules and the implications for chemical bonding.
Molecular Modeling	Biology	10-12	Amino Acid Structure: Students build models of amino acids and study protein structure and function.
Simulation	Biology	9-10	Epidemiology: Simulation of the mechanisms of disease spreading. Students develop simulations of the spread of a disease as a function of different parameters.
Simulation	Chemistry	11-12	Rate Equations: Simulation of reaction rates in simple systems. Students model chemical kinetics and observe the change brought about by changing rate constants.

**Table 1. Examples of Curricular Connections for Various Visualization Tools**

Visualization tools allow access to science content for a variety of students for whom traditional methods of teaching are inadequate. The connection for visual learners is a clear and consistent theme of the projects to date [2, 3, 4]. If we want to have broader participation in science by all students, we need to find ways to reach out to those who have not been well served in the past. Visualization tools offer one avenue of access for these students.

These tools enable a strong constructivist focus in the math and science classroom [5]. They are also available (for the most part) on both Macintosh and PC platforms, eliminating some of the prior focus on the platform and allowing teachers and students to concentrate on effective ways of using these tools in their subject areas.

In order to have a common context, we need to define what we mean by scientific visualization and list reasons and examples for its curriculum “pull” into the classroom. Scientific visualization involves the use of computers to generate representations of large and complex data sets as images. The images can be static or animated and they can represent a range of phenomena from the atomic to the astronomical. Specific examples include MRI imaging in medicine, a wide array of electron microscopy technique for imaging at resolutions to the atomic level, and software to portray the results of large-scale climate models, to name just a few. Figure 1 shows some additional examples with applications to earth science, physics, chemistry, and biology. Table 1 lists specific curriculum connections. The technology is not new, but the increasing power of available computers increases the rich array of subjects that can derive benefit from this technique. The use of scientific visualization is widespread across the scientific community as it is now possible to take abstract concepts and make them concrete. Scientists have made extensive use of this technique and educators are coming to appreciate its value [2]. The challenge is how to successfully move it from research laboratory to classroom.

Scientific visualization does not mean “cutting-edge” only. For any technology to take root in the classroom, it must support current curriculum (see Figure 1 and Table 1) and standards (e.g. the Virginia Standards of Learning [1]). Visualization tools do this very nicely, from dissecting a microscopic animation of mitosis, to looking at earthquakes and faults in North America with a GIS program, to analyzing the physics of a free throw. Table 1 shows just a few examples of specific curriculum applications for each tool. These tools

support the kind of active inquiry and constructivist learning demanded by all the national standards and state frameworks [1, 6, 7, 8].

Gordin and Pea [3] list the following ways in which scientific visualization can impact education:

1. Make a scientific view of the world more accessible.
2. Provide a means for authentic scientific inquiry.
3. Empower students with tools they can use in a wide variety of fields.
4. Lay groundwork to enable students to understand and critique scientific policy.

Each of these methodologies connects strongly with the National Standards in both science and math and reinforces the reforms that have been building over the past few years. They also help address a variety of learning styles opening the doors of math and science to a more diverse population. Teachers are actively looking to improve their practice and scientific visualization offers a way to integrate computers and reform.

A variety of projects have pursued the exploration of how specific visualization tools can impact student learning [4, 9]. Among these are image processing and analysis projects including the Image Processing for Teaching project at the University of Arizona [2], the Co-Vis project at Northwestern University [3], the work of Tanimoto at U. Washington, the simulation-based work of the CC-Stadus/Sustain projects (*Stella*-simulation software) based in Portland, OR, and others. Geographic Information Systems are another class of powerful tools that are starting to find their way into pre-college curricula. The NASA-CCITT project at Prince George's Community College is a good example of this type of work. Each of these projects have used visualization-based software to motivate students of all abilities to the study and deeper understanding of science and math. As Tinker [10] points out, for middle grades "the concentration on modeling, particularly dynamic modeling, will provide a key underpinning for a range of scientific theorizing..." Each project reports success in attracting a broad cross-section of students and taking advantage of their inclination toward visual learning, and each project has a strong teacher development and outreach function.

The different approaches of these projects have led to similar conclusions: visualization tools can enhance the learning and achievement of students in math and science, especially women and students of color (cf. Raphael and Greenberg [11, 12] and Curriculum Technology

Quarterly [13]). These tools can also help to bridge the transition for teachers as they try to incorporate authentic discovery- and inquiry-based learning while still maintaining the content necessary to meet the content standards evolving both nationally and in many states.

In this context, visualization includes working with both real data and simulations. Thus, it includes image processing and analysis, molecular modeling, modeling and simulation, and geographic information systems. There are a variety of different pieces of software for these applications; however, there are many commonalities. Furthermore, visualization tools offer ways to access the myriad of data on the World Wide Web that go beyond the fairly mundane information gathering that makes up much of education's use of the Web. These tools can turn the Web into a laboratory for exploration and discovery.

The critical missing piece in developing the use of these tools is the professional development for both in-service and pre-service teachers. All of the projects mentioned above have had staff development as a central and ongoing feature. However, most of the staff development has gone to in-service teachers, leaving pre-service teachers woefully underserved. Our challenge is to work with collegiate faculty in both education and the content disciplines to integrate these tools in their teaching. There is precious little time to add additional course requirement, yet there is a strong need on the part of aspiring math and science teachers to add these tools to their arsenal (they can also serve to seed interest and training in the schools in which they eventually work). Having college faculty integrate these tools and model that sort of teaching in the methods and content classes will make major strides in bringing the pre-service teachers to a deeper understanding of the value and use of the computers in the math and science classroom. ■

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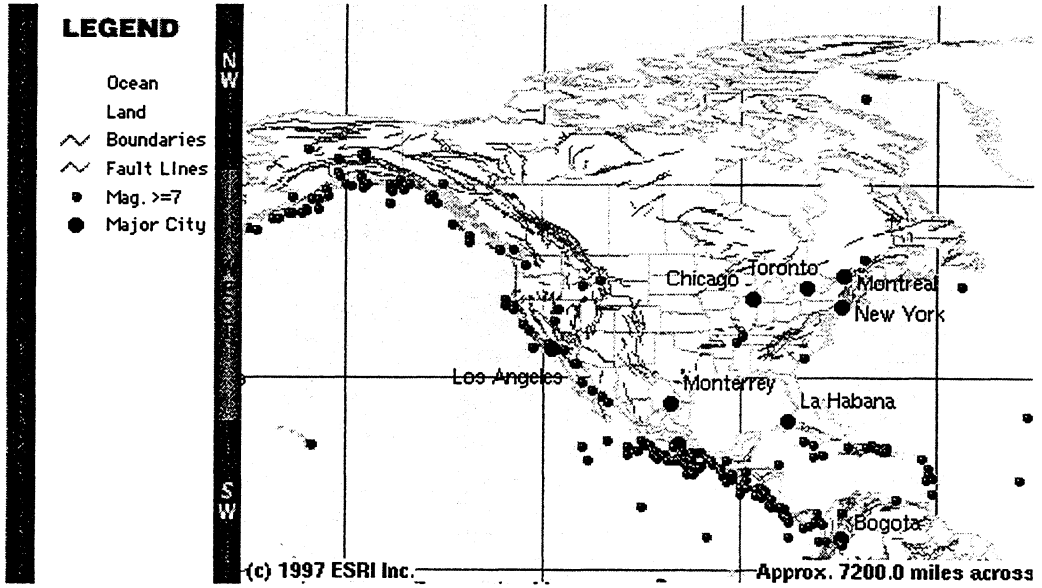


Figure 1a. A GIS map of earthquake sites and fault lines in North America. Data courtesy of ESRI, Inc.

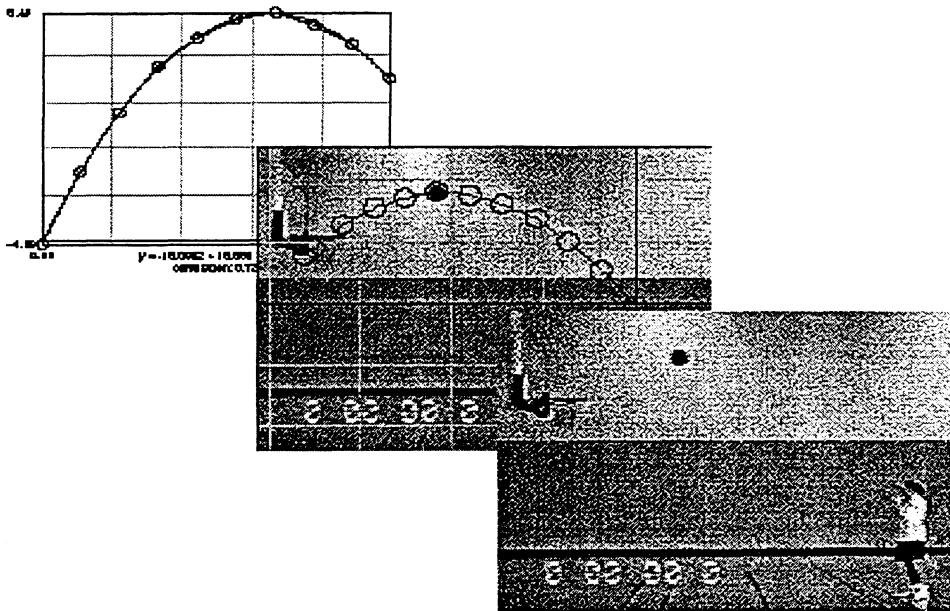


Figure 1b. Trajectory of a free throw. (Image © University of Arizona Board of Regents).

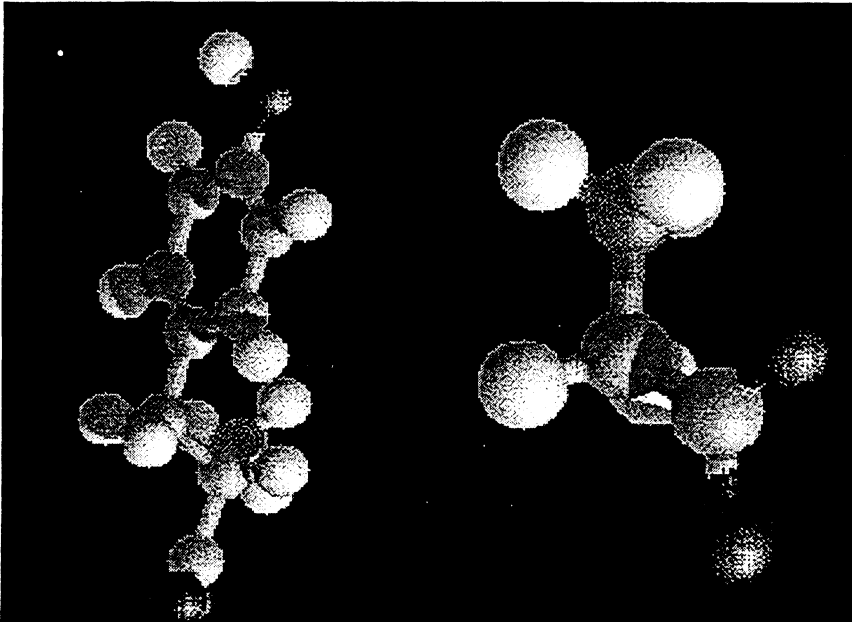


Figure 1c. RASMOL Images of the amino acids tyrosine (left) and glycine.

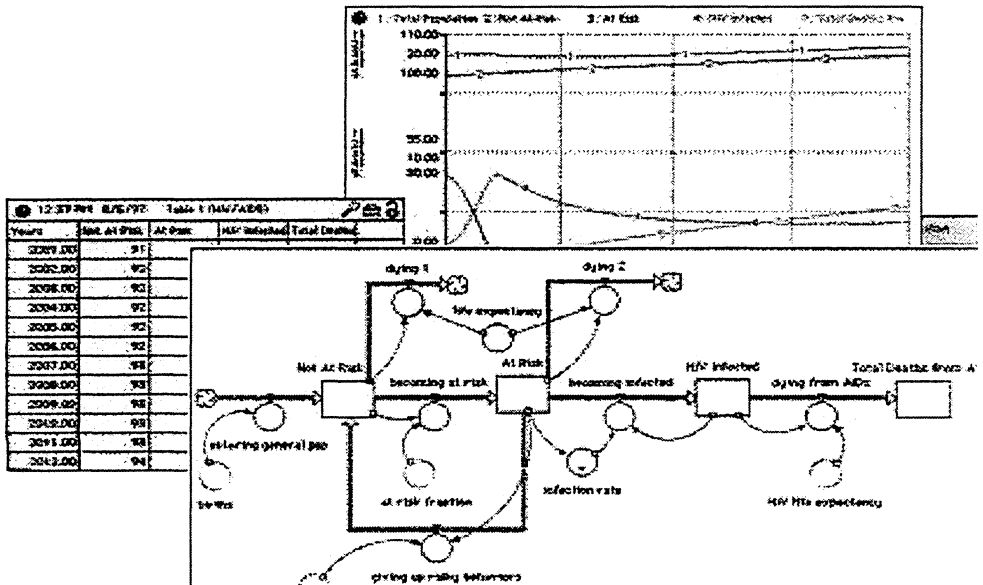


Figure 1d. AIDS infection simulation in Stella. (Images courtesy of High Performance Systems, Inc.)

# TECHNOLOGY INTEGRATION IN A SCIENCE AND MATHEMATICS METHODS COURSE: ADDRESSING VIRGINIA'S COMPUTER/TECHNOLOGY STANDARDS OF LEARNING

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The Standards of Learning for Virginia Public Schools [1] require a high level of knowledge in the use of computers and technology on the part of both students and educators. The Education Department at Mary Washington College has decided to prepare its students to meet this challenge by adopting a strategy of program wide integration of technology, bringing appropriate uses of technology into each education course. This strategy calls for the use of technology by both students and instructors. The course *Instructional Skills in the Elementary Classroom*, a science and mathematics planning course, served as a proving ground for this approach. The integration of technology in this course includes the use of presentation software, spreadsheets, mathematics and science content software, the evaluation of World Wide Web-based resource materials, and a course web page. Halfway through the third semester of this integration experiment, we believe the integration approach to be a proven success. The students enrolled in the course have become enthusiastic users of technology, carrying the skills into other courses and student teaching, and they view the acquisition of these skills as an integral and important aspect of their preparation for teaching careers.

## Introduction

The Virginia Computer/Technology Standards of Learning (SOL), [1] adopted in 1995, require a high level of knowledge on the part of both educators and students in the educational use of computers and associated technology. These Standards appear as lists of skills that students must possess by: the end of the third, fifth, and eighth grade, and by the end of course (prior to graduation.) A separate list of Computer and Technology Skills for Instructional Personnel [2] has also been developed by the Commonwealth of Virginia.

As Virginia's public schools focus on the knowledge and skills listed in the Standards, the Commonwealth's Schools of Education have begun, as well, to implement plans for preparing their students to meet the demands of the Standards. Virginia now requires that graduating education students must possess the knowledge and skills set by the Standards by the year 2002.

In this paper we briefly describe the model the Department of Education at Mary

Washington College (MWC) has developed to prepare its graduates for the Standards of Learning, with a focus on the education course dealing with instructional skills in mathematics and science for the elementary classroom.

### **Mary Washington College Department of Education Technology Integration Program**

Efforts aimed at preparing future teachers in the educational use of computers and technology have ranged from developing a single course focusing on the use of technology in education [3, 4], to providing education students with their own laptops [5]. While a review of the literature suggests that the former approach is still predominant, education departments are attempting to develop new models [6]. The approach taken by Mary Washington College is that of program wide integration of technology. This model calls for the meaningful integration of technology in each education course. Rather than simply providing our students with training in word processing, the use of spreadsheet and database software, and other skills, the use of technology is closely linked to the objectives of the course. Students learn the skills in an educational context and they learn by seeing the use of the particular technology modeled by the instructor and utilized in day to day teaching. If an assignment requires the use of technology, the use must be meaningful rather than serving as a vehicle to teach some computer skill.

### **Instructional Skills in the Elementary School – EDUC 300**

The course Instructional Skills in the Elementary Classroom serves as an example of the application of the program-wide integration of technology. This course, enhanced through collaboration with the NSF-funded Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT), has served as a testing ground for developing new approaches to the teaching of science and math in the elementary classroom. In this course, students focus on the planning and implementation of innovative science and mathematics lessons, developing skills that will prepare them not only for teaching these subjects, but providing them with models for planning and teaching that are transportable to other content areas. This course was one of the first MWC education courses to implement the new technology integration model. The length of this report precludes a detailed description, but examples may be accessed through the course web page [7], much of which is available to the general public.

### **Integration of technology in Education 300**

As with all Education courses at MWC, the integration of computer technology in Education 300 focuses on meaningful educational applications and the demands of the Virginia SOLs. The following brief descriptions provide a summary of how several aspects of computer technology are integrated into this elementary level mathematics and science planning course.

1. **Course Web Page** – While the role of a course web page is still developing in EDUC 300, current use focuses on two areas: an electronic discussion forum, and the posting of students' work for class-wide dissemination. Student responses and reflections, formerly only available to the instructor, can now be posted for the entire classes reading and response. This is especially meaningful in the posting of student's evaluations of educational science and mathematics web pages. Active links in the student's evaluations allow readers to instantly access the page being evaluated. The electronic forum allows a threaded discussion of class work, including assignments and practicum teaching experiences.
2. **Presentation Software** – Presentation programs, such as PowerPoint and Astound, serve as powerful alternatives/accessories to the use of the board or overhead projectors. The use of presentation software by the instructor provides students with models of meaningful integration, while requiring that students develop their own use of the software in groups provides the opportunity to learn the skills needed to develop their own presentations.
3. **Spreadsheet Software** – Spreadsheets provide an excellent tool for developing data tables, charts, graphs, and data analysis skills. These programs allow students to make decisions regarding the construction of tables and graphs and to quickly see the results of their approach. Data can be easily formatted and re-formatted, and the type of chart or graph can be easily modified.
4. **Content Software** – A great deal of content software is available, as commercial (sometime expensive) software, shareware, and public domain freeware. These programs can provide a vast range of educational applications, but, without consideration as to integration in daily planning, are of little value. Class efforts focus on the evaluation of these programs in terms of educational applications and in terms of valid classroom use.

## Conclusion

Perhaps the best evidence for the success of our approach is seen in our students' effective use of many of these techniques in other courses and educational settings. Often, this use is to fulfill another course's use of technology integration, but frequently the students will also apply these integration techniques in areas where no such technology use is required. This is especially heartening in the area of student teaching, where the student teacher might serve as the technology innovator, bringing skills to her or his cooperating teacher. ■

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## **RAPPORTEUR'S REPORT**

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The agenda for the Statewide Conference places a number of important challenges for Virginia's colleges and universities on the table. The new licensure requirements in the areas of mathematics and science for prospective K-8 teachers represent a major, and very much needed, change in current practice. It will be extremely difficult for those of us in the science, mathematics, and education departments to make the necessary changes to respond to this challenge.

This report will attempt to measure the magnitude of the changes needed to produce the requisite numbers of adequately prepared teachers, the extent to which individual colleges and universities have begun to respond to this challenge and our collective capacity to respond to this challenge.

I have found these two days to be highly productive. I welcome the opportunity given to me to give the "Rapporteur's Report" summarizing where we are as we leave this Conference.

As reported by Patty Pitts, Associate Director of Teacher Education and Licensure of the Virginia Department of Education, the Virginia Board of Education has done a great service by clearly stating greatly enhanced science and mathematics expectations for early/primary, elementary, and middle education teacher licensure. The mathematics and science requirements for future elementary school teachers will no longer be the same as the minimum requirements for other humanities majors. Middle school teachers may no longer be certified to teach science and mathematics based upon a general middle school certificate earned by virtue of competence in language arts and social science.

### **TWO CHALLENGES**

The new expectations from the Virginia Board of Education are clear:

1. Future elementary teachers must meet specific competencies in mathematics and science; approved programs must demonstrate that these competencies are met. (Individuals seeking licensure through the alternate route must complete 9 hours each of mathematics and science for PreK-3 endorsement and 12 hours each of mathematics and science for PreK-6 endorsement).



2. Future middle school teachers must either complete 6-12 endorsement which requires majoring in their area of endorsement or complete the middle school endorsement which requires a concentration in the areas that they will teach. *Teachers will no longer be permitted to teach mathematics or science unless they have completed an area of concentration in mathematics or science, respectively.*

The need to develop courses and programs to prepare adequate numbers of future teachers who appropriately meet these licensure requirements presents two major challenges to Virginia's colleges and universities.

It has been apparent throughout this conference that there is universal agreement that future elementary and middle school teachers must have strong academic backgrounds in the areas that they will teach. In reporting on the results of the international TIMSS study, Donna Sterling of the George Mason Graduate School of Education, provided clear evidence that the type of effective teaching that will improve the performance of American students requires that teachers have strong disciplinary background and a deep conceptual understanding of the topics they teach. This agreement provides an important foundation on which to build.

However, we have a long way to go. As Conference Director and University of Virginia Professor of Physics, Steve Thornton, stated, increased science and mathematics teaching licensure requirements are clearly necessary to prepare teachers to appropriately teach the new Virginia SOL. In addition, he stated that "most Virginia colleges and universities are not currently offering the appropriate courses, nor courses taught in the appropriate manner, to meet licensure requirements. Teaching all of the mathematics and science required within even the number of credits indicated by the alternate route guidelines will prove to be very difficult. Both interdisciplinary courses and interdisciplinary programs will be needed."

Jerry Benson, Dean of the College of Education and Psychology of James Madison University, reiterated the view that the sophistication and understanding of science and mathematics that is needed at both the elementary and middle school level is indeed substantial. He emphasized the key role of faculty from the disciplines and challenged us to "think of yourself as one of the most powerful pedagogical models for future teachers - model effective instructional strategies". He also urged those in education to reach out and

effectively involve arts and science colleagues in co-supervising of student teachers, in integrating education methods courses with content courses, and participating in other ways in the preparation of teachers. However, he also cautioned how difficult it will be for teacher preparation programs to require the number of credits in mathematics and science indicated by the guidelines, particularly in the light of all of the other needs of future teachers and the push for a reduction in credit hours for a degree.

## GOOD NEWS

The good news from this conference is that many Virginia colleges and universities are responding in exciting ways to the challenge of developing and offering appropriate courses and programs that meet the spirit of the new Licensure requirements.

### *Programs Preparing Elementary Teachers in Mathematics and Science:*

- Longwood College, through its Liberal Studies Program, requires all future elementary teachers to complete 31 credits in mathematics and science;
- Lynchburg College requires all prospective elementary teachers to complete 22 hours of mathematics and science;
- Virginia Commonwealth University requires all future elementary school teachers to complete a total of 27 hours of mathematics, science and methods courses including one interdisciplinary mathematics/science course and 6 hours of mathematics/science methods.

### *Appropriate Courses for Future Elementary and Middle School Teachers*

- Norfolk State University offers future teachers an interdisciplinary mathematics and science course organized around broad themes and featuring long-term student projects;
- Virginia Tech preservice teachers are excited about their own experiences with an investigative approach to learning mathematics, and are thereby better prepared to provide their students with comparable experiences;
- Radford College is offering a new interdisciplinary physical science course that expects

students to be actively engaged in observation, data gathering, and analysis;

- Hampton University has developed a science seminar for students in their Masters in Teaching program that allows students to share their particular expertise with students from other majors;
- Mary Washington College has developed a geology sequence, taught in a non-traditional discovery oriented style, with an emphasis on collaborative learning in a variety of field settings;
- Virginia Union University faculty are emphasizing experimental design, handling data, and the scientific method for elementary school teachers who find teaching science difficult;
- Mary Baldwin College has developed "Inquiry in Mathematics" that addresses future teacher's attitudes and dispositions, and their beliefs and conceptions of mathematics itself;
- Science and mathematics methods courses are taught in consecutive hours at the College of William & Mary so that the concept of simultaneously teaching appropriately selected mathematics and science topics can be stressed;
- Faculty at the University of Virginia are exploring ways to incorporate more mathematics and science in the culminating field project/thesis experience that is required of future elementary school teachers;
- Faculty from Northern Virginia Community College have developed innovative ways for classroom to teachers to both increase their content knowledge and develop curriculum units;
- Faculty from community colleges across Virginia are accepting the responsibility that they share for the recruitment and preparation of future teachers.

### *Programs Preparing Future Middle School Teachers*

- Virginia Commonwealth University has developed an interdisciplinary science degree that includes concentrations in both mathematics and science, providing the breadth required to teach middle school mathematics and science;
- Science and mathematics faculty at the University of Virginia are exploring the possibility of an interdisciplinary degree in mathematics and science, particularly appropriate for future middle school teachers;
- Longwood College is considering the addition of an add-on middle school endorsement that would build upon the mathematics/science required in the Liberal Studies program, and simultaneously provide students with a masters degree and an additional middle school mathematics and science endorsement.

There is indeed a lot of good news. Five years ago the programs described above that require significant mathematics and science for all future teachers did not exist, and there were very few courses of the type described. We still have a long way to go to respond to the new licensure requirements, but change and enthusiasm and many models do exist in Virginia.

### **WHAT'S IN THE AIR AT THE CONFERENCE?**

When Steve Thornton asked me to serve as Rapporteur, he asked me to report on a sense of what "is in the air". The two themes that I heard most often were the *need for interdisciplinary courses and programs* and the *importance of collaboration between education and science/mathematics faculty*. These two themes were stressed in the plenary talks, and the course work described in the concurrent sessions also reflected these themes. In addition, Robert Watson, long time director of the Division of Undergraduate Education of the National Science Foundation, highlighted each of these themes in his presentation.

### *Need for Interdisciplinary Courses and Programs*

There are many substantive scientific and pedagogical reasons why interdisciplinary courses and programs are important. Most of the reasons center around the fact that public policy issues do not present themselves as disciplinary situations, but rather involve quantitative reasoning and aspects of many scientific disciplines. Most topics of interest and importance to students and to members of the public involve many scientific disciplines; e. g.

the environment, space exploration, sources of energy, the human body. As Robert Watson reported, "the most important work in science is going on increasingly at and across the interfaces of the traditional disciplines." He proposed that "the preparation of all future elementary teachers contain an interdisciplinary emphasis encompassing all the sciences including mathematics and that middle and high school science and mathematics teacher's training be largely interdisciplinary in nature as well."

However, as Rapporteur, I must report that most of discussion around the need for interdisciplinary courses and programs centered around the more prosaic question of how to meet the new Licensure requirements. In particular, Longwood College's interdisciplinary major in Liberal Studies attracted great attention since it provides a way, within a four year program, to meet and exceed the number of credits now required for licensure, while also permitting future teachers to learn about human development and cognition and instructional strategies.

The interdisciplinary courses described at the Conference, including *Experiencing Science*, developed and offered through the Science Museum of Virginia, were of great interest since they seem to many to provide a way to cover all of the different science topics described in the Standards of Learning within the 12 hours of mathematics and 12 hours of science that is the guideline for the PreK - 6 license.

University of Virginia Education faculty discussed the possibility of having the Capstone Field Project/Thesis Experience required of all students be used by some students to fulfill a portion of their science requirement. The idea of having students simultaneously gain a strong understanding of science and mathematics and develop the needed content pedagogical knowledge was stressed throughout the meeting.

#### *Importance of Collaboration Between Education and Science/Mathematics Faculty*

Jerry Benson set the tone by emphasizing the need for collaboration and issuing the invitation: *Let's Dance*. Robert Watson continued the theme by noting that, at the national level, "the norm even at traditional teacher training institutions is more nearly that of armed camps and fortress mentalities, than collaboration."

Perhaps in some institutions, mathematics/science faculty believe that education faculty care only about education and methods courses, and do not think it is necessary for teachers to have a real understanding of the subjects that they teach. Perhaps in some colleges and universities education faculty think that mathematics/science faculty are only interested in providing lecture courses filling the notebooks of students with facts and theories of interest primarily, if not exclusively, to future science and mathematics Ph.D. students. As was clearly demonstrated at this Conference, such views are not prevalent in Virginia!

Indeed, I think that we are prepared to respond to Jerry Benson's invitation to dance, and that we have the makings of a "statewide deal":

- Education Schools will support the development of programs in which students will complete significantly more credits in science and mathematics and be well prepared to teach the topics called for in the Virginia Standards of Learning;
- The science and mathematics faculty will make a renewed commitment to model high quality instruction, including student collaboration, long-term projects and the appropriate use of technology;
- The entire university will consider flexible interdisciplinary degree programs comparable to those being currently offered by Longwood College and Virginia Commonwealth University, and courses will be collaboratively developed that simultaneously meet many needs of future teachers.

## RESPONDING TO THE TWO CHALLENGES

As we leave this conference, I am optimistic about the capacity of those of us who attended this conference to respond to one challenge and pessimistic about our ability to respond to the other.

The first challenge concerns future elementary school teachers and our responsibility to appropriately prepare future elementary school teachers. I am convinced that we will do this. It will require a lot of hard work and good will. We also need the firm commitment of the

Virginia Department of Education in those cases where an institution has not made a serious commitment to addressing this new challenge. The restraints of the total number of credit hours is real, but with the introduction of interdisciplinary majors or other creative approaches, the offering of creative courses, and the willingness of all of us to work together across institutional boundaries, we can succeed.

The second challenge concerns future middle school teachers. Here, the problem centers on the provision of enough teachers to meet the demand. The results of a study by Julius Sigler (see [1]) said it all:

Number of new middle school mathematics/science teachers needed by Virginia School each year, under most optimistic assumptions	150
Annual number of graduates of all Virginia colleges and universities combined who are preparing to teach middle school mathematics/science	15

Of course, it is possible that middle school teaching positions could be filled by individuals who are preparing to teach at the high school level. Unfortunately, with the large shortage of high school science and mathematics teachers, most systems will not be able to recruit teachers from this source.

Other evidence of this situation is provided by a survey currently being conducted on behalf of the Virginia Mathematics and Science Coalition designed to determine the background of those currently teaching in Virginia. The preliminary data confirm our conjecture that most middle school mathematics and science teachers did not initially prepare to teach these disciplines as part of their undergraduate training. According to preliminary data, only 25% of the individuals currently teaching mathematics in middle schools completed the equivalent of at least a 21 hour concentration in mathematics. Even more problematic is the indication that 55% of these teachers studied 12 hours or less of mathematics as undergraduates.

I have become more and more convinced by data provided by TIMSS and other studies

and by discussions of experts across the country that the middle school years are the times when large numbers of American children begin to be unsuccessful in mathematics and science. In order to reverse this failure, we need teachers who are well prepared and committed to providing engaging and effective instruction at this level.

I am concerned about our ability to meet the challenge of preparing sufficient numbers of qualified individuals. The Schools of Education must develop and enhance programs within their institutional structure to prepare their "fair share" of future middle school mathematics and science teachers. Schools of Arts and Sciences and their mathematics and science faculty must develop attractive and appropriate courses and programs for future middle school teachers.

Further, we will need the support of the State Council of Higher Education, the Department of Education, university administrations, local school boards, and the public to provide the resources to recruit and retain these future teachers in our programs. Such support includes higher salaries for teachers, more forgivable loans for future teachers in high need areas, and a climate that encourages the type of interdisciplinary, student oriented instruction that is needed.

## SUMMARY

Overall, I leave this Conference confident that we can take advantage of this great opportunity provided by the Virginia School Board. We can prepare and place individuals in elementary school classrooms with significantly stronger backgrounds in mathematics and science. Making the necessary changes will indeed take the whole university working together.

I look forward to working with all of you in the coming months and years. I can assure you that the Virginia Mathematics and Science Coalition will continue to work to assure that high standards are in place for future teachers and that support for this activity is provided statewide. I hope that many of you will be able to accept the invitation to participate in the Colloquium sponsored by the Virginia Collaborative for Excellence in the Preparation of Teachers to be held July 14-16, 1999 at Mary Washington College. I know that all of us will continue to work to assure that our classrooms provide the best environment for effective



student leaning and that our programs attract talented future teachers with an interest in children and in mathematics and science. ■

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## AIMS & SCOPE

Articles are solicited that address aspects of the preparation of prospective teachers of mathematics and science in grades K-8. The Journal is a forum which focuses on the exchange of ideas, primarily among college and university faculty from mathematics, science, and education, while incorporating perspectives of elementary and secondary school teachers. The Journal is anonymously refereed, and appears twice a year.

The Journal is published by the Virginia Mathematics and Science Coalition.

### **Articles are solicited in the following areas:**

- all aspects of undergraduate material development and approaches that will provide new insights in mathematics and science education
- reports on new curricular development and adaptations of 'best practices' in new situations; of particular interest are those with interdisciplinary approaches
- explorations of innovative and effective student teaching/practicum approaches
- reviews of newly developed curricular material
- research on student learning
- reports on projects that include evaluation
- reports on systemic curricular development activities

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- For article submission, send three copies of the manuscript.
- The body of the paper should be preceded by an abstract, maximum 200 words.
- References to published literature should be quoted in the text in the following manner: [1], and grouped together at the end of the paper in numerical order.
- Submission of a manuscript implies that the paper has not been published and is not being considered for publication elsewhere.
- Once a paper has been accepted for publication in this journal, the author is assumed to have transferred the copyright to the Virginia Mathematics and Science Coalition.
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