

# The Journal of Mathematics and Science:

COLLABORATIVE EXPLORATIONS

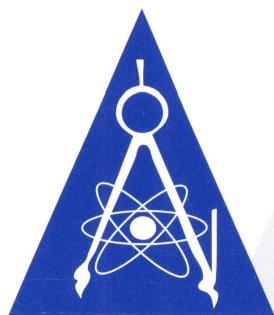
Volume 3, Number 2 Fall 2000

## PART I: SPECIAL ISSUE

### **Programs That Work Conference Proceedings**

Women and Minorities in Mathematics and Science, March 2000

## PART II: REGULAR JOURNAL FEATURES



Virginia Mathematics and Science Coalition

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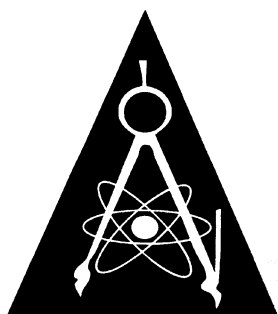
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March 2000

Coordinator for this Special Issue  
Amy Elizabeth Troup  
Center for the Liberal Arts  
University of Virginia



## CONFERENCE FOCUS

# A CHALLENGE TO ALL: RAISING THE PARTICIPATION AND SUCCESS OF WOMEN AND MINORITIES IN MATHEMATICS, SCIENCE, AND TECHNOLOGY

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MARK R. WARNER, PRESIDENT  
LOREN D. PITT, DIRECTOR  
*Virginia Mathematics and Science Coalition*

This issue of our journal is the product of a Virginia Mathematics and Science Coalition (VMSC) conference titled, "Programs That Work" and held in March, 2000 on the issues of raising both the levels of success and the levels of participation of women and minorities in mathematics, science, and technology. Traditionally, these two groups have had low rates of participation in these subjects, and we believe this situation can and must be changed. The conference was to Coalition's first direct assault on the problem.

### **The Need for Change**

At the dawn of the millennium, we can see that ours is a highly technological age. Basic knowledge and literacy in the areas of science, mathematics, and technology is often required for informed private action and responsible civic life, and a high percentage of today's most rewarding careers require substantial levels of accomplishment in these areas. This holds true for professions ranging from telephone technicians to futures traders on Wall Street, from health professionals to designers of web pages. The nation's continued growth in this new economy demands a work force possessing levels of knowledge in the areas of science, math, and technology that are beyond those of any previous generation.

Without the education and skills required by the new technologically dominated economy, students will be denied access to rewarding and lucrative career possibilities. The costs to society of an underdeveloped work force are equally great. For example, our state and national economies are straining today with hundreds of thousands of high-tech positions that remain unfilled because of a shortage of qualified technical employees. This shortfall weakens the companies needing to hire and slows our nation's overall economic development.

Virginia's schools do a wonderful job of preparing our students for their futures. Unfortunately, however, women, African-Americans, and Latino-Americans have traditionally entered the technical fields at lower rates than those of other groups. To give just one example

of this, we observe a fact that is visible in engineering and computer science departments at most American colleges and universities. These departments have low percentages of minority undergraduates, and the scarcity of faculty from these groups is striking. To the extent that we fail to develop the scientific talents of these students, we also fail to develop one of our great resources for economic development and creativity.

### **Moving Forward**

Members of the VMSC strongly believe that many more students can be successful in mathematics and science. The question is how to go forward.

Too often, invisible barriers exist that keep more people from entering the fields of mathematics and science. A striking example of this is the almost universal neglect of girls in class question-and-answer sessions, as noted in Professor Sterling's journal article entitled, "What Does Research Suggest About Successful Programs for Women and Minorities?" featured in this issue. Female students are called upon much less frequently than are males, and their answers elicit relatively shallow responses from their teachers. Except for trained observers, few people are aware that this difference in treatment occurs. In mathematics and science classrooms, many of the students' rewards come with the feelings of pride and accomplishment at the moment of insight when they first understand "how it works." In light of this and the different treatment that girls receive, it may be more than coincidental that both authors have bright daughters who announced at an early age that they were not interested in science. These factors and their effects must be better understood by all in positions to help.

Professor Sterling of George Mason University began the conference by presenting current research concerning the barriers that limit participation and success in mathematics and science, as well as findings on what works to raise levels of success. President Freeman Hrabowski of the University of Maryland Baltimore County (UMBC) gave a moving address on the Meyerhoff Scholars program at UMBC and the remarkable success they have had in educating African-American males who now are reaching the highest levels of excellence in science. Former astronaut and University of Virginia Professor of Engineering Kathryn Thornton spoke on conflicts and opportunities faced by women scientists who are also wives and mothers.

The essential core of the conference was a focus on action, grounded by eleven exemplary Virginia projects that are raising the levels of student achievement in science, mathematics, and technology. Articles and interviews describing the work done in these “Programs that Work” are featured in this issue. These programs, their successes, and their leaders provide the strongest evidence that more students can succeed and that intelligent actions of individuals can make a difference. At the conference, representatives of these programs made presentations and held poster sessions describing their projects and their results. It is our hope that these programs will serve as models for similar efforts across Virginia.

On the second day of the conference, participants focused on policies and actions that can support greater student success. We believe that change occurs through individual actions, but that it will not become permanent and widespread unless it is sustained with systemic policies and support. Starting from this premise, participants formulated recommendations for action by the VMSC. These recommendations appear at the end of the special section of this issue.

Attendees noted on their evaluations that the conference had been a great success. It marked the moment when the VMSC raised questions of equity to the highest levels in its ongoing efforts to improve mathematics, science, and technology education for all students.

We thank all the individuals and organizations that helped make the conference possible. Dominion Resources Services, a long time supporter of the Coalition, hosted the conference at their outstanding training facility in Chester, Virginia. Virginia Secretary of Education Wilbert Bryant spoke to the group and helped us honor the Programs that Work in an awards ceremony. The Collis-Warner Foundation and the IBM Corporation provided generous financial support. Cindy Balderson, Bill Haver, and LaRay Mason did a wonderful job in organizing the conference; Cindy and LaRay did an equally impressive job of running the conference, together with Tracy Pettit and Amy Troup from the University of Virginia’s Center for the Liberal Arts.

To all these, and especially to the conference attendees, we extend our thanks. The conference was the first step of many for the Coalition down the challenging road of educational change. ■





## WHY DO WE NEED PROGRAMS THAT WORK?

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K C. THORNTON

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As a former astronaut, I was fortunate to have had one of the best jobs in the *universe* that one can have with a good math and science education. Even in the best job in the universe, there are degrees of “best,” whether real or perceived. The caste system or “food chain” in the astronaut office was determined less along gender lines than on pilot/non-pilot status. The mission commander is always a pilot. The second-in-command is also a pilot. Some pilots perceive that they are the *real astronauts* and mission specialists (the rest of us) are merely passengers. I perceive them as bus drivers and us as the *real space workers*. In my mind, the pilots’ perception is simply wrong and if they can live with that, so can I. If there were a significant difference in the pay scale between the bus drivers and the real space workers, then the relative values of the jobs would no longer be just a matter of perception—it would be real.

Why do we need programs that work to get women and minorities interested in and qualified for careers in science and engineering? To answer that question we should not look at the few of us who slipped through—there will always be a few who just don’t get the message and, against the odds, become successful in nontraditional fields. We should find the ones who are missing.

White males comprise only 40% of the American population [1]. While not exactly an endangered species, they are a seriously *over*-represented minority in scientific and engineering fields, holding 65% of the jobs [2]. From a national perspective, we simply cannot afford to waste the technical talents of the other 60% of the population. According to projections from the U.S. Bureau of Labor Statistics [3], by 2008 this country will need 23% more physical scientists, 35% more biological scientists, and twice as many computer scientists and engineers as were employed in 1998. The number of science and engineering jobs will grow at four times the rate of all occupations [4]. Not everyone is cut out to be a scientist or engineer, but we must remove the road blocks (overt discrimination) and the speed bumps (less obvious discouragements) to the success of all of those who are inclined toward science and engineering professions.

From an individual perspective, science and engineering jobs pay better than the traditional “women’s work.” Back in my youth (in the *olden days*), a young woman was sent to college for two reasons. First, to find an educated husband with a good earning potential who could support her and, second, to acquire job skills “to fall back on” in the unhappy event that her husband died or left her under less honorable circumstances. Today we know that most of our daughters will work outside their homes at some time during their lives, either as partners with their husbands in supporting their families, or as single heads of households.

Several years ago, I went to a conference sponsored by the American Association of University Women (AAUW) on gender equity, or rather gender inequity, in education. After the conference as I was driving home, I began thinking about the economic inequity between traditionally male-dominated professions and what has been considered “women’s work.” I realized that I was about to pay the girl who cared for my three children for eight hours almost the same amount I paid the boy who mowed my lawn—about an hour’s work. I knew that I could not single-handedly change the economic reward structure of our society, but I could see that my daughters had a choice.

The next day, with all the best intentions, I was determined to teach my oldest daughter, who was about ten years old, how to use a WeedEater. She reluctantly listened while I explained how to operate it, and how safe it was (she couldn’t cut off her foot) although she should wear protective glasses. The lesson was going quite well until I started the WeedEater and, frightened by the noise, she ran away and crashed into a brick pillar. We spent the rest of that Sunday afternoon in the emergency room having the gash in her forehead stitched. She has recovered with only a small scar, the kind that adds character to one’s face, and she does occasionally mow the lawn. I learned a lesson that day (she needed a helmet!) and she learned that there are benefits and drawbacks to one’s choice of career or part-time job. Although babysitting does not pay well, at least it does not usually involve bloodshed.

We must increase the number of young women and minorities in the science and engineering work force for several reasons. We want to create opportunities for all young people for interesting and rewarding careers. We want to increase the number of workers in technical fields to sustain our economic competitiveness. But, there is another important reason: we need a diversity of experiences and ideas in solving problems that affect us all. In his testimony before the Commission on the Advancement of Women and Minorities in Science,

Engineering, and Technology Development, Bill Wulf, President of the National Academy of Engineering, very eloquently made the point that the engineering profession, to the extent that it lacks diversity, is diminished and impoverished. Engineering is by its nature a creative process, which seeks to find the most elegant solutions to problems that also satisfy all the constraints. “In any creative profession, what comes out is a function of the life experiences of those who do it....Without diversity we limit the set of life experiences that are applied and as a result, we pay an opportunity cost—a cost in products not built, in designs not considered, in constraints not understood, and in processes not invented.” [5] In addition to filling the thousands of new high-tech jobs with talented, well-educated young people, we need to ensure that this work force reflects the values, the needs, and the experiences of our nation as a whole.

I cannot offer any special insight or guidance on programs that work for women and minorities—I am one who slipped through—but I do have a few thoughts that I would like to share.

Please don't tell young women, as many of us were told, that “you can have it all.” You can't have it all: a successful career, a wildly romantic marriage, several above average, well-adjusted children, a clean house, gourmet meals, an active social life and your sanity. All of us, whether we are in high tech jobs or not, know that we make choices and compromises every day. After my first child was born and I became for the first time a “working mother,” I was intrigued by magazines that promised to tell me “How To Have A Happy Child And A Great Career,” or other such come-ons. I poured over those articles hoping to find out what I was doing wrong. Eventually I learned that the conclusion of all the articles was that raising a child while building a career is difficult. Well, I already knew that and I did not have time to waste reading articles that told me what I already knew. Let's be more honest with our daughters. Tell them that some choices, such as having a child and a career, are very difficult but also enormously rewarding.

Tell young women that it is not always a nice place out there for those who cross the invisible gender or race lines. Tell them to expect it and to deal with it. Women faculty at MIT felt that they were being discriminated against in a number of ways [6]. Rather than taking their case to court, these scientists sought and received approval to study the situation and to prove their case to the administration. Some inequities were easy to prove. Even though in three of the School of Sciences' six departments, women undergraduates outnumbered men, the percentage of female faculty has remained at 10% for two decades. No woman had ever served as department

chair. Women faculty were granted, on the average, only half of the office space that was allocated to male colleagues. The women proved their point with those data and other harder to quantify inequities, and a modest change is now underway at MIT. The School of Science agreed to increase the number of tenured female faculty by 40% the next year. At this rate, it will take forty years before the 40% of the School's faculty is female.

And finally, ask young women as we must ask ourselves: As women are drawn from the traditional women's jobs for more lucrative high tech careers, who is going to replace them? Just as the projected demand for science and engineering workers will draw women into those fields, a shortage of entrants into traditional women's professions will force us to reassess the value of those professions to our society, and to reward them with the pay and the respect they deserve. We must also not forget the contributions of "non-working" mothers, who are undoubtedly some of the hardest working women I know. Women who helped me take care of my children while I was building a career, "non-working" mothers did more than their share of the carpooling, were coaches and team mothers, ran the PTO, the swim team, the Girls Scouts and Sunday school. Because of them, I did not have to make a choice between having a career and a family. They deserve our respect and gratitude.

I applaud all you have done and are now inspired to do to encourage young women and minorities to continue their studies in math and science, and to excel in those fields. Your continued effort will eventually change the face and the quality of our nation's science and engineering workforce. Thank you for the opportunity to be a part of this conference.

## References

- [1] *Annual Population Estimates by Sex, Race And Hispanic Origin, Selected Years from 1990 to 2000*, U.S. Census Bureau, Internet: <http://www.census.gov/population/www/estimates/nation3.html>
- [2] *NSF Science and Engineering Indicators*, National Science Foundation, 2000, Appendix Table 3-10, Internet: <http://www.nsf.gov/sbe/srs/seind00/>
- [3] Internet: <http://stats.bls.gov/>
- [4] *NSF Science and Engineering Indicators*, National Science Foundation, 2000, Chapter 3, Internet: <http://www.nsf.gov/sbe/srs/seind00/>
- [5] W.A. Wulf, testimony to the Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development, *Committee on the Diversity of the Engineering Workforce* (July 20, 1999).
- [6] B.I. Koerner, "The Boys Club Persists," *U.S. News & World Report* 126, (13) (1999) 156.



# **WHAT DOES RESEARCH SUGGEST ABOUT SUCCESSFUL PROGRAMS FOR WOMEN AND MINORITIES?**

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**This article is based on a keynote address given on March 23, 2000 in Chester, Virginia for the Virginia Mathematics and Science Coalition conference on women and minorities.**

## **Introduction**

By examining the academic performance in science and mathematics for Virginia students in 1999, achievement gaps can not only be identified, but subsequently related to research findings on successful programs for female and minority students in elementary, middle, and high schools.

## **Virginia is Changing**

As an example of changing demographics in Virginia, the Arlington Public School system in northern Virginia has 18,900 students, of which 41% are White, 32% Hispanic, 17% Black, and 10% Asian. Within the last five years, the school district has become a minority majority school system. The rapid rate of change, especially in non-English speaking students, has brought many new challenges to the school district.

## **African-American Students**

Virginia Standards of Learning (SOL) scores are significantly lower for African-American students than the statewide passing rate. Below are summarized the science (see Figure 1) and mathematics (see Figure 2) student achievement for 1999 on the (SOL) test [1,2].

**Figure 1. 1999 Statewide Science Passing Rates for Standards of Learning Tests**

SOL Test	All Students	African-American Students
Grade 3	68	43
Grade 5	67	41
Grade 8	78	56
Earth Science	65	40
Biology	81	64
Chemistry	64	41

**Figure 2. 1999 Statewide Mathematics Passing Rates for Standards of Learning Tests**

SOL Test	All Students	African-American Students
Grade 3	68	45
Grade 5	51	27
Grade 8	60	36
Algebra I	56	36
Algebra II	51	29
Geometry	62	34

Science scores for African-American students are about two-thirds the statewide passing rate and mathematics about 60%. There is no information reported for other minority groups. This data clearly indicates that there is a minority achievement gap to be overcome, at least for African-American students.

An additional observation from the school district test scores is that the higher the school district scores, the higher the minority scores as compared to the statewide passing rate.

## Gender

The only gender related information reported on the Virginia Department of Education website for 1999 is the Scholastic Aptitude Test (SAT-I) mathematics scores. High school juniors generally take these tests because many colleges and universities require these tests for admission. The scores below compare Virginia students to national student scores for males and females (see Figure 3). Female students in Virginia, as well as nationally, score below their male counterparts [3].

**Figure 3. 1999 National and Virginia Scholastic Aptitude Test (SAT-I) Scores**

	National	Virginia
All Students	511	499
Male	531	516
Female	495	484

## Achievement Differences

Achievement gaps appear early and remain throughout school years for minority students. According to the research, poverty and parent education are among the contributing factors for minority students' low performance [4]. In schools with high rates of impoverished children, families tend to move more often which is disruptive to student learning and often causes extended student absences. Schools with high percentages of low-income families tend to have a slowed-down curriculum and teachers with less experience and fewer credentials.

Parent education also appears to be a contributing factor. Parents who have been successful in school are more effective advocates for their children. They tend to do more of the things that make a difference in student performance when raising their children, such as read to their children, answer questions and help their children find out information, seek tutors for their children when they need help, and provide extensive enrichment experiences, such as trips to local parks and museums.

### **Improving Achievement**

Research suggests multiple ways to improve achievement for minority students:

- Preschool programs
- Parent education programs
- Standards with a clear pathway to achievement
- Small classes
- Small schools
- Social and academic support [4].

### **Comprehensive Reform**

Improvement for minority students is most effective when reform is comprehensive and includes:

- All students
- Framework using research
- Whole school/system change [5].

When change is based on a whole school or system, it needs to take into account curriculum that is culturally appropriate, instruction that is culturally informed, teacher professional development, and relations between school and home.

### **Language Minority Research**

Collier and Thomas have been conducting language minority research on over one million students since 1982 in fifteen states [6, 7, 8]. A clear picture is emerging on characteristics of programs that produce long-term student achievement. Effective program characteristics include a focus on enrichment—not remediation—recognition of the power of primary language instruction, and peer coaching. The most effective programs are two-way bilingual followed closely by one-way bilingual. In two-way bilingual programs, half the class speaks one language and the other half speaks another language. Instruction takes place in both languages and the students are each learning the other second language. In one-way bilingual, the entire class speaks the same language, are learning the same second language, and all instruction takes place in both the primary and the secondary language. The least effective programs are ESL pullout and ESL content. A major characteristic of the least effective programs is that they lack academic support for students in their native language: instruction is all in their second language.

To close the gap, English language learners have to learn more than the average student in one year. This shows the great difficulty in closing the achievement gap. Collier and Thomas' research also shows that it takes five to seven years for English language learners in effective school programs to become academically competitive in English.

### **Teacher Professional Development**

For teachers to help minority students learn, they need information about their students and their cultures, culturally relevant curriculum materials and resources, and culturally and linguistically sensitive instructional strategies. Curriculum resources and materials should include role models that are as similar to the students as possible and contain relevant content examples that relate the subject matter being studied to the students' cultural background. Instructional strategies should include hands-on activities, cooperative learning, multiple intelligences theory, and other methods that are helpful for many minority students [9, 10, 11, 12].

### **Gender**

Significant gains have been made in gender equity in the classroom. However, there is still a long way to go. The United States is far ahead of most other countries in achieving gender equity according to the *Third International Mathematics and Science Study* [13, 14, 15]. However, girls still take fewer advanced courses, assume they have lower ability, and have less technology experience outside of school. The largest gender gap for girls is now in technology [16].

Research shows that male and female teachers unknowingly discriminate against girls [17, 18]. Classroom observations show that teachers call on girls less often than boys, spend less time assisting girls, provide shallow praise for girls, give less constructive feedback, and ask few follow-up questions of girls. Responses to girls are usually monosyllabic words such as "good" or "fine." By not asking follow-up questions of girls, they do not have to defend their answers.

### **Conclusion**

In summary, there is an achievement gap for female and minority students in Virginia. If we are serious about eliminating the gap, we need to look at what researchers report as effective program characteristics and effective instructional strategies for female and minority students.



Research suggests some clear characteristics of effective programs. For minority students, preschool programs, small class sizes, and parent education programs are among the program characteristics that make a difference in minimizing achievement gaps. For students who are learning to speak English, enrichment programs that provide instruction in the student's first language, as well as in English, are key. For a gender equitable classroom, teachers need to spend equal amounts of time calling on both male and female students, have all students defend their answers to questions, and provide meaningful feedback.

As demographics change or achievement gaps are identified, success can be achieved by basing programs and instruction on a research-based framework. If teachers are provided with professional education opportunities that expand their knowledge on research-based strategies to meet the needs of their students, success can be achieved for all students in Virginia. ■

## References

- [1] *Virginia Standards of Learning Assessment Statewide Passing Rates Spring 1998 and Spring 1999*, Virginia Department of Education, Internet: <http://www.pen.k12.va.us/VDOE/NewHome/pressreleases/jul2999.pdf>, 1999
- [2] *Board President and State Superintendent Report Significant Improvement in Test Results for African-American Students*, Virginia Department of Education, Internet: <http://www.pen.k12.va.us/VDOE/NewHome/pressreleases/aug599.html>, 1999
- [3] *1998-1999 Virginia Results SAT-I, PSAT/NMSQT, AP Examinations*, Virginia Department of Education, Internet: <http://www.pen.k12.va.us/VDOE/NewHome/pressreleases/aug3199.pdf>, 1999
- [4] *Reaching the Top: A Report of the National Task Force on Minority High Achievement*, The College Board, Internet: <http://www.collegeboard.org/press/html9900/html/991017r.html> (1999)
- [5] "About This Issue," National Clearinghouse for Comprehensive School Reform. *Bookmark*, 1(2) (2000, January) [Online newsletter], Internet: <http://www.goodschools.gwu.edu/bookJan.htm>
- [6] V. P. Collier and W. P. Thomas, "Making U.S. Schools Effective for English Language Learners, Part I," *TESOL Matters*, 9(4) (1999) 1-6.
- [7] V. P. Collier and W. P. Thomas, "Making U.S. Schools Effective for English Language Learners, Part II," *TESOL Matters*, 9(5) (1999) 1-6.
- [8] V. P. Collier and W. P. Thomas, "Making U.S. Schools Effective for English Language Learners, Part III," *TESOL Matters*, 9(6) (December 1999/January 2000) 1-10.
- [9] *National Science Education Standards*, National Academy Press, Washington, DC, 1996.
- [10] *Principles and Standards for School Mathematics*, National Council of Teachers of Mathematics, Reston, VA, 2000.
- [11] R. E. Slavin, *Cooperative Learning*, Allyn and Bacon, Boston, MA, 1995.

- [12] T. Armstrong, *Multiple Intelligences in the Classroom*, Association for Supervision and Curriculum Development, Alexandria, VA, 1994.
- [13] *Pursuing Excellence: A Study of U.S. Eighth-Grade Mathematics and Science Teaching, Learning, Curriculum, and Achievement in International Context* (NCES 97-198), U.S. Department of Education, Washington, DC, 1996.
- [14] *Pursuing Excellence: A Study of U.S. Fourth Grade Mathematics and Science Achievement in an International Context* (NCES 97-255), U.S. Department of Education, Washington, DC, 1997.
- [15] *Pursuing Excellence: A Study of U.S. Twelfth Grade Mathematics and Science Achievement in an International Context* (NCES 98-049), U.S. Department of Education, Washington, DC, 1998.
- [16] *Gender Gaps: Where Schools Still Fail Our Children*, American Institutes for Research, American Association of University Women Educational Foundation, Washington, DC, 1998.
- [17] *How Schools Shortchange Girls*, Wellesley College Center for Research on Women, American Association of University Women Educational Foundation, Washington, DC, 1992.
- [18] "Early Learning Effects on Female Students: Gender Bias in the Classroom," *Dateline NBC*, Hosts Jane Pauley and Stone Phillips, NBC Network, 1993.



## **BRIDGES — MATHEMATICS SUPPORT FOR THIRD-GRADE GIRLS**

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### **The Idea**

“I’m no good at math.” These are words that we never want to hear from a female student at Venable School in Charlottesville, Virginia. This feeling of not being successful in math and science can start early. In spring 1997, the Venable School standardized test results for the third grade showed that female students scored, on average, 13 percentile points below the third-grade male students on the math subtest of the Stanford 9 Achievement Test.

The goal of BRIDGES is to break this cycle of lower performance. In academic year 1999-2000, funds from a Virginia Power grant (available for the past two years) enabled eight female, third-grade students to receive additional mathematics instruction through an extended-day program. The girls were selected by their teachers as needing additional math instruction in order to meet third-grade objectives. Once the students were identified, their parents were invited to a meeting to learn more about BRIDGES and to sign the contract if they wanted their daughters to participate. All who attended the meeting signed up for the program.

So that the girls might become comfortable using mathematical concepts, instruction was embedded in practical, everyday situations, like preparing a meal, eating dinner at a local restaurant, performing a community service project, and starting a small business. These types of projects demonstrated to the girls that math is not simply a paper-and-pencil activity; it is something we all use on a daily basis.

Students were required to stay after school from 3:00 p.m. to 4:30 p.m. two days each week. We also involved parents as partners throughout the school year. They participated in at least one evening activity for each project. To develop a home support system, parents assisted with and monitored their child’s nightly mathematics homework assignments.

### **The Context**

Venable is a public, urban elementary school that serves grades K-4 with an enrollment of approximately 300. One-third of the students qualify for free or reduced-price school meals. Approximately one-third of the students are members of minority groups, with African-American students representing the largest part of this group. Some students live close enough to walk, but

the majority is bused from their neighborhoods to Venable. Our school's goal is for all students to be successful and to meet the high achievement standards set in the Virginia Standards of Learning. To meet this goal, each student's academic needs have to be analyzed and an instruction and support program put in place. BRIDGES is one-piece of a comprehensive support system for students.

### **The Project Activities**

"A Candlelight Dinner" was the focus of instruction for October. Students used addition, subtraction, multiplication, estimation, measurement, and working with fractions to prepare a budget, shop for supplies, and modify recipes to prepare for their parents. In addition to purchasing the supplies and preparing the food, students were responsible for renting the tablecloths, china, and flatware to set a formal table. Related topics covered included nutrition and the social skills of manners and proper behavior at a formal table.

"Night on the Town" was the focus for November and December. Students continued to use addition, subtraction, and multiplication skills. They also began to calculate percentages, estimate costs, and learn to handle money as they planned a dinner for their family at a local restaurant. The culminating activity was for each student to treat her family to dinner at a local restaurant. The students were responsible for calculating the bill (food, beverage, gratuity, and sales tax) and counting out the cash to pay the bill.

"Developing Entrepreneurship" was the focus for January, February, and March. After surveying consumers to determine the need for a product, they decided to start a small T-shirt business around the theme of the Earth Day celebration. A local businesswoman spoke to the students about how to start a business. Students developed a business plan, sought a loan for the start-up costs, and developed a marketing strategy. Mathematics was used to determine interest payments, pricing of the product, and profit/loss margins.

"Community Service" in April and May allowed the students to take some of the profits from the T-shirt enterprise and return these to the school community. Venable has a schoolyard wildlife habitat of plants to attract birds to our grounds. The community service project goal was to build birdhouses to be placed on the school grounds. Students researched the types of birdhouses that would attract the desired birds. They used measurement, geometry, and knowledge of hand tools to plan and build the houses. Parents were included in the cooperative effort of installation in the schoolyard.

## Evaluation

The BRIDGES students attended the extended-day sessions regularly—rarely missing even one afternoon. They approached each task with enthusiasm and a positive attitude. The girls came to think of BRIDGES as a special club. They spoke fondly of others in the group and proudly identified themselves as BRIDGES girls. And word about the program's success has gotten out to the community. In fact, BRIDGES has such a good reputation that, since the first year, parents have been requesting that their daughters be allowed to take part.

The chart below shows that, of the eight girls who participated, seven passed the third-grade mathematics SOL test; these same seven also were graded "good" or "outstanding" on their final nine-week report card.

Student	SOL Score (400 Needed to Pass)	Report Card Grade for the Final 9 Weeks
T.B.	452	G+ (good)
S.E.	434	O (outstanding)
L.J.	273	N (needs improvement)
A.P.	512	O
S.P.	426	G
J.R.	417	G
A.S.	463	O
R.S.	443	O

## The Budget

### Equipment

Tableware rental (cloths, china, crystal, utensils)	\$ 95
Hand tools (hammers, nails, saws)	\$ 75
Raw materials (food, beverage, lumber, posts)	\$ 280
Total	\$ 450

### Supplies

Restaurant (\$15 per person)	\$ 360
School (pencils, paper, calculators, etc.)	\$ 90
Snacks	\$ 150
Total	\$ 600

### Personnel

All volunteer	\$ 0
Total	\$ 0

Total	\$1,050
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**INTERVIEW WITH MALCOLM JARRELL**

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** I have been involved with public elementary schools in the City of Charlottesville for 23 years as a classroom teacher, reading specialist, and coordinator. Similar to most people right out of college with an undergraduate degree, I thought I knew everything or at least everything that was worth knowing. After teaching for a while and reflecting on my practices, I started seeing a pattern—students who entered the classroom at the beginning of the year academically behind their peers ended the year still behind. I started looking for reasons why. It wasn't until graduate course work that I realized how little I did know. With each class I took, many questions were answered; however, even more questions were raised in my mind. The more I learned, the more I realized I had still to learn.

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** Upon starting my present job as Instructional Coordinator at Venable School, the school's principal, Ron Broadbent, shared some standardized achievement data from the previous year that showed female students scoring thirteen points less than male students in mathematics. Edie Wheeler, the Gifted Specialist, and I came up with the idea for an after school program for third-grade girls that would give them additional mathematics instruction, and opportunities to apply the mathematics learned to real life situations—preparing a meal for family, eating in a restaurant, starting a small business, and performing community service. Both Edie and I had been involved in pieces of each of these activities before as classroom teachers, but nothing as intensive and comprehensive.

**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** The unexpected outcomes were:

- the amount of parental involvement. We had parental involvement as a requirement for students to participate. However, in most cases parents went above and beyond the program expectations.

- the girls came to see BRIDGES as a club. For the most part, the participants were average to below average students. They had not been involved in "remediation" programs in the past. They quickly developed a group identity and took pride in being part of the after school activities.
- most girls made significant growth in their understanding of mathematics and developed a positive attitude about their abilities as math students.

**Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on BRIDGES? What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?**

**A:** The lesson—all students can learn and be successful. The ability is there; the part that is variable is the time. Some get there quickly with little or no support from others, while there are some who need additional instruction and opportunities to practice to get there.





# PROJECT BEST: A COLLABORATIVE PROGRAM TO RECRUIT TEACHERS AND ENHANCE SCIENCE PERFORMANCE OF MIDDLE SCHOOL STUDENTS

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## Introduction

Project BEST (Basic Educational Skills and Training) is a collaborative mentor-tutorial program between Virginia Commonwealth University's (VCU) School of Education and Department of Mathematical Sciences, and Richmond Public Schools. Project BEST is one of the teacher recruitment initiatives of VCU's Teacher Preparation Collaborative. The Collaborative, a consortium of seven four-year colleges and three community colleges, seeks to strengthen the mathematics and science preparation of pre-service and in-service elementary and middle school teachers.

The overall goal of Project BEST is twofold. First, it provides a comprehensive program to enhance the academic performance of at-risk middle school students in mathematics and sciences in preparation for success in an academic high school track that in turn facilitates college admission.

Academic success at the middle school level frequently determines readiness for a college preparatory track in high school. Middle school students who have a solid foundation in mathematics and sciences are more likely to be successful in college preparatory courses than those without a foundation in math or science [1]. Mathematics, in particular, has long been considered the "gatekeeper" to college admission [2]. At the middle school level, Project BEST endeavors to increase the numbers of students who are eligible for college admission and who are prepared to persist to graduation from college.

Second, the project serves to recruit college students who are competent in mathematics and sciences for teaching in elementary and middle school classrooms. In academic year 1999-2000, 76 college mentors worked with 112 at-risk students in nine of the ten middle schools in the Richmond Public Schools.

In Virginia, two-thirds of middle school mathematics teachers do not have the equivalent of a major in mathematics and large numbers are teaching out of their field. Teachers who are not specifically prepared to teach in a field are unlikely to have the requisite content knowledge and

pedagogical knowledge to provide quality instruction [3]. At the college level, Project Best seeks to increase the number of prospective teachers in the pipeline, particularly minorities, who are competent in mathematics and sciences.

When Project BEST began in 1989, its goal was to increase the retention rates of the minority college student and at-risk middle school student populations, and through the partnership, to also increase academic performance of middle school students. Since that time, retention rates at the University and in Richmond City's middle schools have improved. In 1997, as the needs changed, the emphasis of Project BEST shifted to address the need for recruitment of undergraduate students for careers in teaching and to improve academic performance of middle school students in mathematics and sciences.

### **Program Components**

The four basic components of Project BEST may be easily replicated:

First, a three-tiered mentorship program in which college faculty and middle school teachers serve as mentors to college students, and college students serve as mentors to middle school students. Faculty mentors are available to assist the college students with issues related to professional growth, career planning, and personal development. Their role is not to serve as a faculty advisor, but as a confidante and friend to the students. The college students serve as role models to the middle school students. They help them gain a vision of who they can become if they remain focused on academics and prepare to attend college.

Second, a mentor/tutorial program with paid VCU students mentoring and tutoring middle school students in mathematics and sciences two days each week. The middle school teachers closely monitor the after-school tutorial program, maintain portfolios with class materials to direct the students in the tutorials, and are present to provide assistance and direction to the mentors during the tutorial sessions.

Third, workshops for college students and a special series of math/science workshops for middle school students that enhance academic skills. At the beginning of each school year, an orientation session is held for the college students giving them the opportunity to understand the organization of the program and their responsibilities as mentors/tutors. The content of the workshop also includes information on adolescent growth and development, the content of middle school curriculum, skills assessed by the Virginia Standards of Learning sub-tests in mathematics and sciences, strategies for tutoring in mathematics and science, and strategies

for building durable self-esteem in at-risk children. The public school teachers, administrators, and VCU faculty serve as facilitators and consultants during this session. Each participant receives a *Project BEST Handbook* that outlines program procedures and individual responsibilities in Project BEST. Information on curriculum and tutorials is also included.

The workshops held for the middle school students serve to reinforce class content as outlined in the school's curriculum. For the past two years, a series of Saturday math and science enrichment seminars were implemented to review the concepts included on Virginia's Standards of Learning sub-tests in mathematics and science. Over the years, workshops have been held on note-taking, critical thinking, and test-sophistication skills. To get the parents and siblings involved in the Saturday workshops this year, an "Algebra Family Fun Day" was held with prizes and a pizza party for the participants.

Fourth, a series of cultural events on campus and in the community are run to enhance self-esteem of middle school students and community acculturation of the college students. These events also allow the mentors and the middle school students an opportunity to get to know each other in informal settings. Over the years, the students have participated in trips to amusement parks, plays, basketball games, and picnics. Last fall, the students and their mentors visited the "Splendors of Egypt" exhibition at the Virginia Museum.

### **Criteria for Selection**

Middle school students selected for the program must have demonstrated potential for academic success either through grade-point averages or test scores. Students who are academically capable but who have been determined to be at-risk because of discipline problems and frequent absences may be invited to participate in the program. Further, math and/or science teachers recommend students who they feel will benefit from having a college role model and tutor. Teachers and administrators at each school select the students who will participate in Project BEST.

College students selected as mentors for the program must have at least a 2.0 cumulative grade-point average and prior experience working with children. Students must have an academic major in math, science, or a related field, or in teacher education. Students who have *not declared* a

major are invited to apply for Project BEST. Those selected are assigned a faculty mentor in the School of Education and are actively recruited for the teacher preparation program. Each student writes a statement explaining why he or she is interested in the program and participates in a formal interview.

### **Evaluation**

The project continues to meet its goal of teacher recruitment. Approximately twenty percent of the current Project BEST mentors are teacher education majors. The Project Best director will monitor the number of students who are retained in the teacher preparation program, graduate, and obtain licensure for teaching.

The mentor/tutorial program is evaluated as successful based on academic progress of the middle school students, as evidenced by improvement in grades in mathematics and science or maintaining good grades in mathematics or science each marking period, passing scores on the Standards of Learning sub-tests in mathematics and science, and a reduction in absences and discipline referrals. In an earlier study of Project BEST [4], the students in the experimental group as compared with a control group consisting of students not participating in the project, had higher grades, greater self-esteem, fewer absences and discipline referrals, and were more likely to accept responsibility for the academic successes and failures. This higher level of performance of the Project BEST students has been consistent since the inception of the program.

The director constantly monitors the program throughout the school year through informal contacts. At year-end, the Project BEST director conducts formal interviews with the principals and lead teachers to determine program strengths and weaknesses, modifications needed, and overall performance of mentors. The project director also administers formative evaluations of activities/workshops to the middle school and college participants throughout the year. A summative evaluation is administered at the end of the school year following a meeting of mentors and selected Project BEST lead teachers and school administrators.

### **Stories of Success**

Project BEST received national recognition with awards from the American Association for Higher Education and the American Association of State Colleges and Universities for excellence in the area of strengthening relationships with local school districts.

The project is making a difference in the lives of students by positively influencing their academic performance and attitude, and thus, affecting their personal lives. Personal comments of

college mentor/tutors and middle school students in the program best communicate the impact of the program on the lives of its participants.

A seventh grade student noted, “Before I got into Project BEST, I guess I wanted to go to college, but I really didn’t think about it. Now, I know I’ll be interested in going to college and getting a degree.” A 1993 VCU graduate who served as a mentor for three years and is now employed as a manager in a local business stated, “We have good relationships with our faculty mentors and with faculty at the middle school. All of us, tutors and students, have become good friends. It’s like a little circle—like a little family.” A 1996 VCU graduate who was a first-generation college student began working with the Project in 1993 as a student mentor. She is the mother of three children, one of whom was a participant in Project BEST, and went on to become a mentor when he enrolled at VCU. She stated, “I saw the positive things this program did for my child. I wanted to do what I could to help.”

### **Recommendations**

A program like Project BEST should be coordinated at the school level and closely monitored by its administrators and teachers. Mentors should work directly with the teachers to determine the middle school students’ current academic status and needs, as well as strategies, activities, and resources available to address those needs.

Teachers should explore several variations of the mentor/tutor configuration. In some cases, a one-to-one configuration may be optimal while in others one-to-two or two-to-two configurations would achieve maximum results. Male students in the program expressed a preference for working in small groups while female students reported that they prefer their “own” individual college mentor/tutor.

Parents should be informed of the goals of the project and should be committed to involving their children in all of the program’s activities. Saturday seminars and after-school tutorials represent a tremendous sacrifice to a child who would rather be playing baseball. Parents may need to know of the importance of enrollment in an academic high school track and may be interested in learning about financial aid and summer preparation programs, as well as other initiatives, to help in planning for their child’s eventual admission to college. Parental involvement is crucial.

Finally, it is vital that all of the participants in the program are committed to its success. Commitment is evidenced by each individual's full participation in all project activities. In the event individuals are not able to fulfill their responsibilities to the program because of competing priorities, adjustments may be possible--if not, new participants should be recruited.

### **Budget and Funding**

The Virginia State Council of Higher Education for Virginia funded the project. In subsequent years, support for the program came from the Jessie Ball DuPont Fund and VCU. Currently, funding is provided by the National Science Foundation with additional support from VCU and the Richmond Public School System.

### **Summary**

Project BEST is a unique program that helps to improve mathematics and science achievement of students while simultaneously recruiting college students for teaching careers, and providing opportunities for them to serve as mentors and tutors for middle school students. The program consists of four main components: mentoring, tutoring, workshops, and cultural activities for the college students and middle school participants. Teachers and administrators in the middle schools and middle school students' parents are also involved in the program. In the eleven years of its existence, Project BEST has had more than 300 college participants, some of whom remained in the program for the entire period of their undergraduate study and are pursuing careers in teaching, and more than 500 middle school children, whose performance and attitudes have shown improvement attributed to the project.

The design of Project BEST is simple enough that it can be replicated at a modest cost in most communities. It is truly a program of which it can be said, "There are no losers. Everyone is a winner!" ■

### **References**

- [1] *Academic Preparation for College*, The College Board, New York, 1983.
- [2] *Planning for college: Some issues for students and parents to consider*, The College Board, 2000, Internet: <http://www.collegeboard.org>
- [3] *Preparing Middle School Mathematics and Science Teachers: A Challenge for Virginia*, Mathematics and Science Coalition, White Paper, 1999.
- [4] D.J. Simon, D.F. Reed, and M. Clark, "The effect of cross-age mentoring on the achievement and self-esteem of at-risk students in middle school," *Research In Middle Level Education: Selected Studies 1990*, 14(1) 11-22.

**INTERVIEW WITH DIANE J. SIMON**

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** In 1988, during my first year as Assistant Dean in the School of Education at Virginia Commonwealth University, Dr. John S. Oehler, Dean of the School of Education, and then Associate Provost, Dr. Alvin Schexnider, asked that I develop a program to improve the retention of minority students at the University. Project BEST began as a retention initiative and was, and continues to be, only one of my responsibilities in my role as Associate Dean. Project BEST is more of a labor of love because of the close personal contact with our students, the public school children, and relationships with public school teachers and administrators.

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** During my tenure as Director of the Division of Education and Psychology at Virginia Union University, I was asked to write a partnership proposal related to tutoring and mentoring public school children who were at risk of academic failure and in need of guidance and support. That proposal, then entitled The Kenan Project, was funded for a five-year period. Although I took another position during the first year of the project's implementation, writing the proposal gave me an opportunity to study the literature on tutorial program design, configuration, and implementation; and, to think about the types of support, academic and personal, that at-risk children may appreciate, be challenged by, and enjoy.

**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** Perhaps one of the most gratifying consequences that resulted from Project Best, is the expansion of the program from one to three middle schools in Richmond during Academic Year 1998-99 and to nine of the ten middle schools the following year. The personal relationships forged between the college students and the middle school children have been gratifying to see. As Project BEST began in 1989, I hear from Best mentors who have graduated from the University and have kept in contact with their former mentees through the years. Only last month, I had a Project BEST mentee



come by the office to visit me. This student is graduating from a four-year college in December 2000 and is planning to teach. Another example is a VCU student whose son was a middle school mentee in Project BEST. She served as a mentor and tutor because she wanted to make a contribution to the program that she felt had helped her son. Her son eventually enrolled at the University and also served as a mentor and tutor in the program. Through the years, we have learned of former mentees who have graduated with honors from high school and have gone on to college. As one of the major goals of BEST is to be prepared to take and succeed in an academic high school track to facilitate college admission, it is always gratifying to hear of our former middle school mentees who have reached this goal. A number of VCU students in Project BEST undecided on a major when they enrolled, selected teaching as a major. One stellar example is a graduate who now teaches at the Governor's School in Richmond.

**Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on Project BEST? What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?**

**A:** Perhaps the greatest reward in working with Project Best is to see the improvement in middle school students' grades in mathematics and science from one marking period to the next which indicates positive results from participation in the program. The mutual benefit of the program is the reciprocal relationship that exists between the college students and their mentees. The middle school students are getting assistance to help them succeed in an academic high school track in preparation for college admission. The college students are getting an opportunity to gain a first-hand perspective of what teaching is all about while providing an important service to children.

In our meetings with the college mentors or in informal conversation, I take a delight in hearing about the mentors' successes with mentees who grasped a difficult concept or whose grades improved after having had a difficult time. Hearing from parents who believe that the Project is helping their children, and from the public school teachers who also believe that the program is making a difference in the lives of students is also very gratifying. VCU students who are undecided on a major when they matriculate and then decide to major in our teacher preparation program is another indicator that the program is meeting its goals. Working with Project BEST also keeps me in touch with the "real" world of public schools. The program affords me another opportunity to stay involved with the local schools.

## **BRIDGING THE GAP: THE CLASSROOM AND THE “REAL WORLD”**

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P. STRICKLER

*Center for Applied Technology and Career Exploration, Franklin County, Virginia*

The Center for Applied Technology and Career Exploration in rural Franklin County, Virginia was created to improve students' career choices in an area with high unemployment. The Center is a unique endeavor because it represents a total community effort in preparing students for the American workforce of the 21<sup>st</sup> century. Community leaders, business and industry representatives, local colleges and universities, parents, and teachers have worked collaboratively to develop the curriculum used by the Center. Focused on problem solving, critical thinking, and rigorous study, this curriculum emphasizes advanced technology skills and hands-on learning.

### **Origins of the Center**

Franklin County Virginia Public Schools—a system of 6,959 students and 509 teachers—serves a rural population. Forty percent of the population over 25 years of age does not have a high school diploma, and 32% of the students qualify for free or reduced meals. In order to address this issue, the voters of Franklin County approved a school bond referendum in November, 1994. This bond was \$14,684,000, of which \$6,000,000 was used to set up the Center for Applied Technology and Career Exploration. Local businesses, parents, professors, and community groups worked cooperatively with the school system to open the Center in 1997 with the purpose of integrating technology into the academic program, so that students at a critical age, specifically girls and minorities, could see the possibilities and long-term benefits of their educational efforts. In addition, the Center devotes a large majority of its focus to the female and minority populations.

### **Program Description**

All Franklin County eighth graders spend one full semester at the Center. Those ninth graders who choose to continue studying at the Center select three areas of study from among eight career modules: arts, engineering/architectural design, environmental/natural resources, finance, health and human services, legal science, manufacturing, and media design. Each of the eight career modules includes technology skills specific to the selected career focus. The modules also integrate into each career investigation content outlined in the Virginia Standards of Learning [1] for core subjects: language arts, social studies, math and science. In the technology

field, students master skills in areas such as, understanding storage retrieval and transmission technology; becoming proficient in keyboarding and word processing; creating complex documents with databases and spreadsheets; using local and worldwide networks; developing hypermedia home page documents; and, applying technologies to problem solving and critical thinking activities. Within each curriculum module, students master applications specifically designed for the real-world workplace. The library is electronically based, and the Center has an interactive laboratory for distance learning and multimedia communication.

### Modules

Some excerpts from our web site [2] and a short summarization of three of the modules, Engineering/Architecture Design, Finance, and Health and Human Services are given below.

#### Engineering and Architectural Design

*Would you believe it if someone told you students understood how to do CAD designs before they reached their sophomore year in high school? Or perhaps that students even understood how to develop interior and exterior design layouts? What if someone told you that students were working on a transportation project with the Virginia Department of Transportation?*

Students in this module gain practical and intimate knowledge of the challenges and opportunities offered in the fields of engineering and architecture, by using hands-on activities to solve real-life problems. The “interns” encounter a variety of problems that require them to work both individually and in teams, such as creating floor plans for a house and some new playground equipment. Through this activity, the interns: examine how structures influence the skyline in urban environments; explore interior design and tower design; and, look at dam and road construction. Their study of road construction consists of calculating route and construction costs of the alternatives with local engineers of the Virginia Department of Transportation, as well as examining the impact of the interstate on local economy and environment.

#### Finance

*Did you ever think that someone at the age of fourteen could understand the principles behind finance? How about understanding how to manage their money? What if they could even understand the principle concept of consumerism, and how it affects jobs and international trade agreements?*

Interns in this module explore three facets of finance—job acquisition skills, consumer skills, and money management skills— in order to bring to life realistic financial situations that they may well encounter as adults. Among some of the activities, they are required to write a résumé, complete a job application, attend classes on appropriate dress and deportment, and finally, participate in a job interview. As their studies progress, they receive a paycheck and are encouraged to open an account at the “First CATCE Finance Bank” where they receive personalized checks and statements, and are allowed to make deposits and withdrawals. By the end of their studies, the interns gain an intimate knowledge of reading financial documents, managing credit card debt, calculating net pay and withholding taxes, and evaluating insurance policies through their positions at the bank. Their daily progression through the chores and responsibilities associated with such concepts as corporate structure and the principles of sole proprietorship, brings this module to life.

#### Health and Human Services

*What would happen if there was a tanker disaster on school property? How would you prepare for any mishaps on camping expeditions? And how do you educate the public about wellness?*

These are just some of the aspects of a module aimed at preparing the interns for all the facets of the health and wellness field. The interns are trained in the areas of problem solving, crisis management, and wellness. Working with technology to determine the answers to complex problems, such as controlling infections and ecological disasters, requires the interns to effectively communicate their ideas through the use of spreadsheets, multi-media presentations, and parliamentary procedures used in town hall-like settings. From the larger situations, interns move on to the fundamentals of managing individual crises associated with emergencies; they are taught how to assess situations, make contact with emergency personnel, assist the victim(s), and provide solutions. Interns are shown that learning first aid and earning CPR certificates is not enough; they must also exercise the critical thinking skills necessary to become efficient, caring, and technologically prepared health care workers. To further their understanding of how some crises may be avoided, instructors teach the interns the value of nutrition. They learn the nutritional merits of foods, how to count fat grams and calories, and the long-term benefits of exercise. Running a health care facility not only emphasizes how many occupations are needed to maintain a well-run organization, but also that maintaining healthy lifestyles means happier, more productive employees.

**Staff**

Teachers serve as mentors and learning facilitators. All activities are based on the students' need to experience hands-on learning and develop critical-thinking and problem-solving skills. Teachers are committed to providing discovery learning through electronic research and multisensory experiences using presentation software. Innovative assessment procedures require students to develop electronic portfolios to showcase the work they do. Virtual environments, digitally performed original music compositions, animation clips, digitally generated images, web pages, composite drawings, and multimedia presentations are some of the products shown in students' portfolios.

Teachers have many opportunities for staff development, most of them in the world outside the school system. Many work directly with local businesses to learn the realities of the profession represented in the modules, and all attend conferences and take college courses in related fields. A typical example is the two-week trip to the New York Stock Exchange by the two teachers planning the finance module. Teachers receive extensive technology training through a five-year, \$1.5 million grant from the Department of Education Technology Innovation Challenge Grant program.

**Technology Infrastructure**

The Center provides one computer for every two students, and all classroom spaces are linked to the schools' intranet and other networks, such as the internet. A library-like virtual center replaces the traditional media center; and, a state-of-the-art interactive laboratory, equipped with a rear-screen projection system, interactive whiteboard capability, a document camera, outlets for laptop computers, and a touch panel lectern, is also available. Because of its advanced nature, local businesses, community groups, and higher education institutions also make use of this laboratory, thereby creating yet another link between the Center and real-world businesses and institutions.

Students use CD-ROMs, videodiscs, and numerous online and electronic resources to conduct research. Teachers discuss responsible use of these electronic resources, and students are trusted with unrestricted access. In each career module, students also work with software used in business and industry. For example, students analyze crime scenes in the Legal Science module with advanced image processing; they develop computer-generated composite images of their classmates. In the Media Design module, students use PageMaker and PhotoShop to create

brochures and flyers. High-end Macintosh workstations are available to create CD-ROMs and video segments for the web while studying television production.

### **Future Challenges**

While implementation of the Center for Applied Technology and Career Exploration has progressed smoothly, it is not without its challenges. For example, the almost overnight creation of new software and equipment often does not allow the Center's teachers to learn to use the new materials in advance of their students. The evolving curriculum, team planning sessions, and the need to constantly update technology skills require a great deal of teachers' time off-contract.

### **Conclusion**

At the Center for Applied Technology and Career Exploration, curriculum delivery is provided in an applied, hands-on fashion. Students are immersed in real problems posed in manageable units of study and projects, so that instructors may serve as facilitators, guiding students toward practical solutions. Along the way, students are also taught the value of skills that are implied, but not listed in a job description; such as, cooperation, listening, sharing information, being goal oriented, articulate, and organized. Thus, real-world applications of their studies are enhanced by the opportunity to directly apply learned content through technology and personal skills.

It is our mission statement at the Center that what students learn should: be relevant to family, community, and workplace; be student-centered and performance-based; and, stem from mastery of curriculum objectives jointly developed and maintained by community leaders and educators. Ultimately, the Center's efforts will bridge the gap between the classroom and the "real world" so that **all** students may become effective members of a dynamic workforce. ■

### **References**

- [1] *Standards of Learning for Virginia Public Schools*, Board of Education, Commonwealth of Virginia, Richmond, VA, 1995.
- [2] Center for Applied Technology and Career Exploration Web Page, <http://www.frco.k12.va.us/catce1/cmain.htm>

**INTERVIEW WITH PAUL STRICKLER**

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** I taught public education in North Carolina for seven years before going back to graduate school for a Master's degree and Ph.D. in Education Administration. The twist was that in teaching in a poor county in North Carolina, I saw how education for the poor folk was not what I got and being white, middle class and having a strong family in the city. I have always dreamed of a school that truly did for the children, loved the children, educated the children—no matter what—and provided that extra measure of "whatever" that we got. To me, it always seemed that the poor and the minorities in this country had to start the race about a hundred yards back from the starting line. And everyone else blamed them because they couldn't finish the race like the other people.

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** This is the biggest innovation for me and the one I have felt has come the closest to what I have dreamed about. The rest of my work has been trying to promote a climate of trust and goodwill toward children and have them believe that we are truly on their side, and not just saying that and doing something else. You can tell if a school is built around the children in a very short period of time once you enter the building. Children who are smiling and educators getting into instruction is very clearly seen. Learning is not a "neat" process of rows of desks and quiet children.

**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** Unexpected consequence—NO!—I always said that innovation and being in front of the pack is difficult because the pack wants to pull you back or take shots at you until they catch up. The hardest group of people to win over is the middle-to-upper class white parents who got to where they are by traditional schooling and most likely being in the college-bound tracks, and wanting nothing less for their child.

**Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working with the Center for Applied Technology and Career Exploration? What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?**

**A:** The greatest lesson to learn in any innovation is to have strong support during the time one is trying to put the program in place. Next, would be that innovation is costly and again the support is necessary to success. A very supportive superintendent is a must!

Rewards are many: (1) I was there from the beginning and understand it like we wished it to be; (2) the staff has been great—true innovators and dreamers of what education could be in this country; and, (3) the faces of the children who are the winners in this. Until this past year, I have never had a child that came to me as principal and said, "Thank you for letting me be here."

What is the greatest benefit? That is easy--let's all hope that public education learns to do the right things in educating the children in this country and stop the politics. The politics are killing education. How would you like to have the governor of Virginia and friends telling your doctor how the by-pass surgery should be done?





## GEOMETRY AND MATHEMATICS THROUGH BRIDGE BUILDING

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J. JOYNER

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I teach mathematics at Norview High School, one of five high schools in the Norfolk City public school system. The school population is made up of approximately 1,700 students from middle- to low-income neighborhoods. The ethnic mix of the student body is approximately 70% Black, 25% White, and 5% Other (principally Filipino). I have been teaching in public schools for six years after an eighteen-year career with the United States Navy. In those six years, I have taught almost every math subject offered at the high school level in the Norfolk Public School system.

Early in my second year of teaching, the school system's senior coordinator for mathematics asked me if I would be interested in teaching an inaugural *Mathematics Through Bridge Building* class for gifted middle school students in the Extended Day Program. Since I have always tried to help students make connections to real-world uses of mathematics, this course appealed to me; however, I knew little about both bridge building and teaching elementary engineering concepts. Fortunately, the Virginia Beach Public Library proved to be a treasure chest of books on bridges—many written for school-age children. With two weeks' preparation under my belt, I began teaching the bridge building class and have continued to do so for the last five years.

Middle school students who wish to take enrichment classes attend the Extended Day Program. The subject matter of the classes goes beyond the scope of what is available to them at their current grade level. Students must apply and be accepted into the program and their parents must pay a small fee for their participation in each class. Most of the classes meet one afternoon per week for two hours over the course of several weeks. Though we originally met for eight weeks, the *Mathematics Through Bridge Building* class now runs for ten weeks.

The bridge building class is always an exciting experience; the students are inquisitive and energetic, and each class is unique. Every year I learn more about the subject matter through researching and preparing for class. I do think, though, that I learn more from my students than I teach them. Now, that's fun! Because each year's class ranges in size from eight to sixteen

students, the dynamics change not only from year to year, but also from activity to activity. Overall, the students have reacted positively to the math, engineering, and physics principles to which I expose them. I combine these three principles with video, computer, and hands-on activities, then stand back and watch as the students become "detective engineers." There is no single activity that I do in class that has more student enthusiasm than the application of geometry and bridge construction concepts to the building project. The project requires after-school time and students who otherwise do not come for after-school help in geometry will wait in line, if necessary, to use one of eight classroom computers.

As I stated before, each year the class content evolves. I am constantly searching for new activities and for ways to modify current activities to encourage student involvement. I firmly believe in the appropriate use of technology in the classroom; this course is no exception. Bridge building activities may require anything from simple paper and pencil or poster board for designing and building, to internet connections and computer software. My greatest concern is the lack of resources available given the number of students served. While group work is useful for certain activities, it would be beneficial if each student could individually explore his or her ideas, then share the results with the larger group.

The program has no formal assessment. Classes in the Extended Day program are not graded, but the excitement and enthusiasm displayed by the students affirm my belief that what I hope to achieve is taking hold. I simply want students to develop and experience a concept of math that is positive, as well as applicable to their lives.

Most teachers may not have the opportunity to offer such a set of activities in a non-traditional classroom setting such as the Extended Day Program. For teachers who wish to offer a project or extended activity in a regular classroom, I have included a brief overview of how I have structured my bridge building activity in my second semester geometry classes. Teachers who wish to use my overview may change anything and everything in it to suit their individual needs, resources, and desired outcomes.

The budget for the bridge building course is fairly minimal, with funding coming through the Norfolk Public Schools Gifted Center. Also, I have personally purchased items to use in class, but this has always been my own decision. Not every activity or resource is used each year in the bridge building class. Resource items range from poster board, scissors, tape, staples, and graph paper to Legos kits, Knex bridge kit, and Bridge Builder software [1,2]. The most expensive items I use are the Knex comprehensive bridge kit (currently \$140, but smaller basic

kits are available for less) and the Bridge Builder software (currently \$99 for a single license with lab, school, and network packs available) [1,2]. Funds to support a bridge building activity or project may be available within individual schools and districts, and also through grants, government sources or education foundations. You may obtain additional information by e-mailing me.

### **The Idea**

Students are exposed to a practical use of geometry through the research, design, simulated construction, and testing of a truss bridge. The basic engineering principles behind a truss are easily understood since it is based on the simplest type of polygon—the triangle.

General background information is available – even in school libraries with few engineering-specific resources. Encyclopedias contain descriptions, histories, and the various uses of the truss. Public libraries are likely to have even more engineering-specific resources, such as civil engineering books, for students and teachers. There is a wealth of information on the World Wide Web. Schools of civil engineering at universities and colleges, as well as individuals with an interest in bridge construction, post many of these sites. Most of the sites include photographs and other graphics, some of which are interactive. These bridge sites are generally more current than information available to students in printed form and many are geared to students or other laypersons.

This project is conducted in three phases over a period of approximately three weeks. Most work is done outside the classroom. In phase one, students prepare a one-page summary of their research on trusses. They submit it to me for a quick review to ensure that they have the basic concepts of what a truss is and how it is used.

In phase two, students design a simple, two-dimensional truss bridge on graph paper. The bridge must meet the dimensional criteria of building a truss bridge using the software Bridge Builder (Pre-Engineering Software). The bridge must span a 400-foot body of water, rise no more than 100 feet above the roadway, and extend no more than 65 feet below the roadway. Other basic criteria, such as the maximum allowable length of a building member (box girder), maximum number of members allowed, and maximum number of joints allowed, must be used by each student in the graph paper design of the bridge. At this phase of the activity, students bring to play their knowledge of triangles (types, properties), symmetry, and aesthetics in designing their bridges. The graph paper design is also submitted to me for a quick review. I check to see that each student has met the basic design criteria, and whether each has used a scale to aid in the

simulated construction of the bridge in the final phase. I encourage each student to be as thorough as possible in the graph paper design of the bridge as this will make the final phase of activity easier. Since I can't tell if a student's design will work or not by visual inspection alone, I ask questions to ensure that each student has properly considered or used the various design concepts and requirements. Some designs look more promising than others, but it is not until the bridge is actually constructed on the computer, and then tested, that a student knows if a design will work.

In the final phase, students "construct" their graph paper-designed bridges using Bridge Builder software. This software package is designed specifically for students in grades six through twelve and is easy to use. Once constructed on the computer, each student tests his or her bridge. The first test is a static—dead load—test to see if the bridge will support its own weight. The second test is the dynamic—live load—test to see if the bridge will support a forty-ton truck that is driven across the bridge on the computer monitor. The first test must be passed before the second test can be run. If either test fails, the student must analyze his or her design and reconstruct the bridge until it passes both tests. Once a successful bridge is "built," each student must then improve the design or construction to increase the overall efficiency rating of the bridge.

### **The Outcomes**

The project in *Mathematics Through Bridge Building* allows students to use their knowledge of line segments, angles, triangles and polygons, proportions, symmetry and reflection, aesthetics, and basic engineering principles associated with trusses. Students are exposed to basic schematic drawings through the printed copies of their bridges produced by the software. Each student reviews the basic analysis of his or her bridge as printed out by the software. That analysis contains basic information, such as the wire diagram of the bridge, the length and angle of each member in the bridge, the amount of compression or tension in each member, the efficiency of each member, as well as the overall efficiency of the bridge.

In addition to using and reinforcing research skills, students make use of practical geometry skills, graphing skills involving the use of scales and proportions, computer skills through the use of the Bridge Builder software, and analytical reasoning skills in testing and improving the designs of their bridges. Although the application of engineering and physics formulas is not required of the students in computerized construction and testing of the bridges, students are exposed to those basic principles and to the fact that the software is using engineering and physics formulas in its testing and analysis printout.

**Evaluation**

As indicated above, student progress is assessed at three points along the way: when the research summary is submitted; when the graph paper design is submitted; and, when the bridge construction is successful, and then improved. A copy of the project sheet that each student is given appears as an appendix.

**References**

- [1] Knex Education Web Page, <http://www.knexeducation.com>
- [2] Pre-Engineering Software Corporation Web Page, <http://www.pre-engineering.com>

## APPENDIX

Geometry B End of Semester Projects  
Mr. Joyner

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Choose one of the following special projects to do. The project will count as a **double project grade**. If you choose to do both projects, indicate which is the primary project; the other project will count as a **bonus project grade**. The project must be turned in no later than June 8, 1999.

## 1. Bridge Building

a. Research what a **truss** is in engineering and explain how it is used in building bridges. Your explanation must be coherent, use correct grammar, and be at least one page (typewritten). Cite all references used. If you do not cite references used, no points are earned. (20 points)

b. "Design" a truss bridge on **graph paper** using the requirements of the **Bridge Builder software**. "Construct" and test your bridge using Bridge Builder, which is available on the classroom computers. Once your bridge passes all tests, print the bridge's engineering data. Save the bridge to floppy disk. (60 points)

c. **Improve the design** of the bridge to get a lighter and more efficient bridge. Print the bridge's engineering data. Save the bridge to floppy disk using a similar name. (20 points)

Initial Efficiency	Final Improved Efficiency	Points Earned
Less than 30%	Less than 50%	10
Less than 30%	More than 50%	14
More than 30%	Less than 50%	17
More than 30%	More than 50%	20

## 2. Geometry in Art, Architecture and Engineering

a. Find an artist, architect or engineer, or a style of art, architecture or engineering that makes strong use of geometric shapes. Research the subject as well as the design layout of several newspapers. Create a **newspaper "front page"** on posterboard that tells the story about your findings. Your newspaper must have a title, as must your article. The front-page story must include at least three graphics. The story must be coherent, use correct grammar, and be at least 400 words in length (typewritten).

Category	Points Possible
Newspaper Title	5
Appropriate Article Title(s)	5
Newspaper Design Layout	10
Appropriate Use of Graphics	15
Article(s) Content and Presentation	65

## INTERVIEW WITH JOSEPH JOYNER

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** I never intended to become a teacher when I was in college. I tutored when I was in college, but that was as close as I came to any sort of teacher preparation. When I graduated, I had taken no education courses. It was a few years later that I had the opportunity to become a classroom teacher for an adult education program. I fell in love with teaching during that first week! A year later, I had been offered a faculty position at a community college in the City University of New York. For three years, I was a co-director of the math lab at Bronx Community College. While there, I took my Master's degree in mathematics education, while also teaching classes at Bronx Community College and Lehman College. Shortly after I got my master's degree in early 1976, I joined the U. S. Navy (this had been on a back burner) as an officer. So began an eighteen year break in my short teaching career. I knew that when I eventually left the Navy that I would return to teaching. When the time came to end my Navy career, I took all of the courses needed to get a Virginia teacher's license. I walked out of the Navy and directly into the classroom at Norview High School in 1994 and am there today. So, yes, there were many twists along the way.

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** My first involvement in a program of this nature was in December 1995. I had just finished my first year of public school teaching, and I was asked by the mathematics coordinator for Norfolk Public Schools to consider teaching a *Mathematics Through Bridge Building* class to middle school students as part of the after-school program for the school system's Gifted Center. I said yes, despite not having any background as an engineer or any resources to teach the course. That first course was fun for me—an adventure. I gave a workshop presentation of the bridge building course at the Virginia Council of Teachers of Mathematics annual conference in Charlottesville in 1997. I have taught the class for five years now and each ten-week offering has been different than the ones before it. I am now scheduled to teach the course in a new summer enrichment program for the school system's Gifted Programs Office.



**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** No, not really, other than I think I learn more than I teach the kids and perhaps have more fun at it too! I am told that the course is a very popular one now in the Gifted Center's Arts and Sciences Program.

**Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on *Mathematics Through Bridge Building*? What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?**

**A:** The greatest lesson that I have learned is that if you can unleash a student's creative imagination, then learning will happen. I have seen students who perhaps were interested in little else in geometry come alive with this project. I have had geometry students standing in line after school waiting to use computers in the classroom in order to work on this project. The greatest benefit is that real learning happens and doesn't have to be forced. Perhaps through exposure to projects like these, teachers will have ideas for other projects that can similarly capture the creative imaginations of students—once that happens, stand back and watch the students take off! Projects take time and sometimes are hard to fit into a curriculum that may be focused on standardized test scores. But if they are productive and can be made to fit, the benefit is well worth it. I need more like this one in all of my classes!! I'm searching.

## VCEPT/GATEWAY 2000 PARTNERSHIP PROJECT – ADVANCED SCHOLARS PROGRAM

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H. JOHNSON  
*Henrico Public Schools,  
Virginia Commonwealth University, Richmond, Virginia 23284*

During the summer of 1999, the Virginia Collaborative for Excellence in the Preparation of Teachers (VCEPT) and Gateway 2000, funded by Richmond Public Schools through a National Science Foundation grant, provided a three-week Advanced Scholars Program at Virginia Commonwealth University (VCU) for forty middle school students. The Advanced Scholars Program was modeled after the Young Scholars project that VCU, with National Science Foundation (NSF) support, organized from 1991 to 1997 for rising seventh graders from the Richmond metropolitan area.

The Advanced Scholars Program was designed to meet the needs of rising seventh grade students with a high potential and/or interest in mathematics and the sciences from populations traditionally underrepresented in these fields, including African-Americans, Native Americans, females, and students from economically disadvantaged backgrounds.

The goal of the program was to nurture the interest of the Scholars and provide them with appropriate information and encouragement, so that a large percentage will prepare for careers in mathematics or science. The program featured career exploration, group research projects, and enrichment topics in mathematics and physics, as well as technology not usually included in the standard school curriculum. Special attention was given, however, to some of the components in the Virginia Standards of Learning.

Secondary and middle school teachers, who serve as “clinical faculty” in the Richmond Area Mathematics Teacher Professional Network, joined with VCU faculty in providing instruction for the five components of the program: mathematics, physics, statistics/calculator, research, and career exploration.

### **Mathematics**

Math instruction featured cooperative learning through group logic puzzles, the development of deductive and inductive reasoning skills using puzzles, and the use of graphing calculators. Also, students collected many different types of data, expressed it in a table format,

founded a rule (formula or equation), and graphed the data when appropriate. Some of the mathematical content included: order of operations, discovering patterns, deciphering messages, Origami, Sieve of Eratosthenes, and fractals.

### **Physics**

Because the idea of physics has a daunting reputation for students, the formal physics instruction was focused on investigative, hands-on approaches. They were too busy exploring static and current electricity to be intimidated. Through clear and specific activities designed to illustrate the basic principles, students gained a more thorough understanding of:

- How sockets work or fail to work in an electrical arrangement;
- How to construct and use an electrical device for testing whether or not materials allow electrical charges to move through them;
- How to identify which kinds of materials are conductors and which are nonconductors;
- And, how to determine which materials can be electrified and which cannot.

### **Statistics/Calculator**

The first goal of this component of the program was to instruct students on how to use the graphing calculator to perform algebraic calculations, create a coordinate system, construct a function table, trace and zoom on a graph, and enter, sort, and sum data. The second goal was to show students how to interpret data by using different types of graphs; such as, bar graphs, circle graphs, line graphs, stem and leaf plots, box and whisker plots, and scatter plots. When appropriate, students were also taught how to create these graphs using the calculator.

### **Research**

Assisted by a teacher, the students worked in teams of eight to ten students on a group research project. These projects focused on statistics and were modeled after projects developed in the Quantitative Literacy Program. With the support of advisors, the groups were responsible for the design of the experiment, for carrying out the experiment, and for preparing written and oral reports.

### **Career**

On Career Day, students were divided into two groups—one group visited VCU'S Medical College of Virginia and the other group visited the Virginia Department of Transportation. Accompanied by the staff, participants spent the day with a mathematician,

statistician, computer scientist, engineer, draftsman, doctor, nurse, and/or research scientist. These professionals showed students their workplace and explained the nature of their jobs. Students then interviewed their hosts using an instrument they had developed to solicit information on educational requirements for the job, career path, career satisfaction, and job frustration. Each group made an oral presentation of their visit to the other students.

A typical program day consisted of the following events:

9:00 – 9:05 a.m.	General announcements
9:10 – 10:10 a.m.	Mathematics class-----Groups 1 and 3 Physics class-----Groups 2 and 4
10:15 – 11:15 a.m.	Mathematics class-----Groups 2 and 4 Physics class-----Groups 1 and 3
11:20 – 12:15 p.m.	Statistics instruction and/or graphing calculator instruction
12:15 – 1:00 p.m.	Lunch
1:00 – 2:50 p.m.	Work on group research project and/or career exploration
2:50 – 3:00 p.m.	Prepare for dismissal

Ronald Bradford, Mathematical Instructional Specialist, and Cynthia Gentry, NSF Grant Coordinator, organized the recruitment for Richmond Public Schools. Forty students were selected; each one received free hot lunches, a stipend, and a graphing calculator. During the final week of the program, the Scholars were invited to bring their parents to a banquet where the program activities were highlighted.

One month after the program ended, a random sample of participants was surveyed by phone. More than half of those surveyed—nine out of fifteen—reported having learned “a lot,” while the remaining students said they had learned “some.” The physics component was a favorite among those interviewed; students enjoyed the hands-on activities, particularly the electric motor and the static electricity experiments. Instruction in the use of graphing calculators

was also quite popular. A handful of students remarked on the novelty of using the calculator: “It was new for me”; and, “It was the first time I ever used a high-tech calculator like that.”

Half of those interviewed liked all the activities and found the three-week program helpful. Some students offered criticisms of the course, many of which dealt with the math component. Three students stated that most of the class was a review, and one student stated that they had already done most of the activities in the fifth grade.

Several Scholars offered suggestions for program changes. Among the suggestions were calls for longer hours, adding an extra class, and extending the program length. Other recommendations included conducting classes simultaneously, or having smaller classes in order to give more attention to individual students. Most noteworthy, perhaps, were two students who suggested adding new content and “harder, more advanced” work.

In conclusion, the Scholars were very positive in their overall responses to the survey. While physics emerged as a clear favorite, many students also enjoyed the mathematics experiences and the visits to the field sites. The notion of a more advanced curriculum with opportunities for Scholars to learn new content appears to be of interest to some students.

### **Budget**

The total budget for the program in 1999 was \$35,577. The budget was significantly lowered by the fact that the program model and many associated activities had previously been developed and refined through a series of NSF sponsored Young Scholars Programs. There were ten staff members, including a project consultant and coordinator, a daily project leader, two lead teachers, four “clinical faculty,” secretarial help, and one student assistant. Salaries, wages, and benefits totaled \$23,495. The total amount devoted to participants’ support, including stipends, travel, meals, and graphing calculators, was \$10,607. Other direct costs, such as materials and supplies, amounted to \$1,475. VCU waived all indirect costs, provided all classroom and laboratory space, and supplied grant contract accounting—a total value of \$11,036. ■

**INTERVIEW WITH HENRY JOHNSON**

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** My original goal was to become a mathematician. When entering college, I majored in mathematics, with a minor in physics. Before going to college, one of my high school teachers, Mr. Earnest Parker, suggested that I consider teaching as a career, but I told him that I was not interested in teaching. After graduating with a degree in mathematics, I looked at several occupations. At that time, my career choices were limited in the Richmond area. Relocation to the larger cities in the northeastern or western sections of the United States was required, if I wanted to start a career that involved mathematics or science. I was about to make the move, when Mr. Parker called and asked if I would consider teaching for one year before I decided to relocate; I said yes. Although I had never taken any education courses or student taught, my first year of teaching was a wonderful experience. I had good role models in high school and college that provided me with excellent teaching techniques. After the second year of teaching, it became apparent that I love to teach, so I decided to take the necessary education and methods courses that would allow me to obtain a teaching certificate.

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** During my teaching career, I have been involved in programs such as the Upward Bound Program and other programs that help high school students, as well as elementary teachers, to become interested in mathematics and sciences. Later, I got involved with the Young Scholars Program. Because of the success of that program and the positive experiences obtained by the staff and participants, the Advanced Scholars Program was modeled after the Young Scholars Program.

**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** While working with the Young Scholars and the Advanced Scholars Programs, I realized that middle school students were fun to teach. Also, by working with teachers from various backgrounds and with different teaching styles, it was easy to realize that no matter how long you have been teaching, you can always learn something from your peers.

**Q:** Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on the VCEPT/GATEWAY Advanced Scholars Program? What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?

**A:** We were able to reach the students while they are impressionable and still enjoy mathematics and science. Although they came from different schools, the participants benefited by learning to work as a team, and they realized that mathematics and science can be fun subjects.

## LEARNING ON THE HALFSHELL

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M.H. DUFFEY and C. ROBERTS  
*Portsmouth Public Schools, Portsmouth, Virginia*

At William E. Waters Middle School in Portsmouth, Virginia, approximately 120 seventh grade students are involved in oyster restoration. Two dedicated teachers, science teacher J. Catherine Roberts and mathematics teacher Margaret H. Duffey, lead the students. The goal of this project is to integrate mathematics and science problem solving into the educational experiences of seventh grade students using cutting edge technology. These students, in partnership with the Virginia Marine Resources Commission (VMRC), the Chesapeake Bay Foundation, and local universities, are involved in biweekly monitoring of oyster growth and water quality, as well as the subsequent analysis of this data. Information from current research and innovative technology is incorporated into the project activities.

The activities involve at-risk, low-income students, many of whom are under-represented minorities in the fields of mathematics and science. Most of our students come from single parent homes with parents employed in blue-collar occupations. Although education is of prime importance in these homes, parents are often unable to provide the significant experiences included as part of this project.

According to the Virginia Marine Resources Commission, the oyster stock in the Chesapeake Bay has declined to less than 1% of its historic abundance. A current Environmental Protection Agency (EPA) Zone Three program initiative is to reconstruct oyster reefs as brood stock sanctuaries. The Chesapeake Bay Foundation is committed to establishing 5,000 acres of restored oyster reefs in both Maryland and Virginia to increase the abundance of oysters from 1% to 8% of historic levels over the next 10 years. Our goal is to involve seventh grade students in the oyster-restoration process and to increase public awareness of this vital environmental issue. To increase the abundance of oysters, innovative technology must be used. Information from the most current research has been incorporated into an interdisciplinary curriculum.

Seventh grade students have built a "Taylor float" from materials donated by the Chesapeake Bay Foundation. The float is placed in the Chuckatuck Creek and filled with seed oysters. Oyster spat for the seed oysters is obtained from a population of oysters in the Lynnhaven River that has survived the viruses Dermo and MSX. Floating cages place oysters in



moving water where food is abundant and away from the bottom where siltation can occur. Oysters grown by this method are less affected by the sediment that can clog their gills, slow their growth, and possibly make them more susceptible to disease. Finally, growing oysters in floating cages can protect them from predation by blue crabs, raccoons, and other animals.

Students monitor water quality and inspect oysters for mortality during their monthly field trips to the Chuckatuck Creek site. Students also document important aspects of the oyster population, such as the changes in the mean size of the oysters. During the school year, the oysters will increase in size from  $\frac{1}{2}$  inch to nearly two inches. Ultimately, the monitoring data produced by the students will supply valuable information for evaluating the effectiveness of their restoration efforts. These findings will become part of a database created by the Chesapeake Bay Foundation, thus providing a service for Virginia and for future generations. At the end of ten months, the students stock the oysters on a newly created inter-tidal oyster reef sanctuary in the Elizabeth River.

Growing 2,000 oysters from seed and stocking a local sanctuary enhances the students' knowledge of mathematical concepts through the use of hands-on experience, real-world data collection, and analysis. While in the field, students are introduced to the use of probeware and graphing calculators. They also utilize laptop computers to record data in spreadsheet format. As students review and evaluate cumulative data, they become proficient in graphing data to show trends and in employing slopes to interpolate and extrapolate. The data produced by the students supplies valuable information to the Chesapeake Bay Foundation.

In science classes, students study the physical, chemical, biological, and geological characteristics of the Chesapeake Bay ecosystem. They complete activities to demonstrate the connection between increasing the oyster population and the improved water quality in this environment. In the mathematics classes, students learn proper measurement techniques, data collection on both the computer and graphing calculators, and how best to analyze collected data. These skills, coupled with experimental techniques used in water quality tests, enable the students to make connections between mathematics and science. This project results in increased interest and enthusiasm for these subjects, and prepares seventh grade students for advanced math and science courses. Current research indicates that students entering the workforce of the 21<sup>st</sup> century need a strong background in math, science, and technology.

The activities of the project were integrated with the Virginia Standards of Learning for math and science. It was necessary, therefore, to check for knowledge and understanding

throughout the project. This was done through teacher-generated tests and alternative assessment activities. Pre- and post-tests on the knowledge of seventh grade science and math skills were also administered to the participating students to assess their progress. These tests indicated an increased knowledge of the Chesapeake Bay environment.

When the students were asked to reflect upon their experiences, they had the following comments to make:

“There are not a lot of oysters; I went on the *Baywatcher* and we hardly pulled up anything.”

“I learned how dirty the Chesapeake Bay is.”

“Before this year, I didn’t know that oysters can clean the bay extremely fast.”

“The bay is important. Oysters are in the bay, and their population is declining.”

“The bay is threatened because the oysters are dying.”

“I know now that we have to help the oysters.”

“We need to start telling people what to do and what not to do to the Chesapeake Bay.”

Because Portsmouth is a poor school system, the two teachers involved in this project seek funding each year to continue the oyster restoration project. Student transportation to the oyster site is needed each year, as well as money for substitute teachers. Grant money allows our students to learn and to actually experience the Chesapeake Bay in its natural setting, as opposed to simply reading about it in the classroom. Since this project addresses a current environmental need and provides a successful learning experience for children, funding from agencies and foundations has not been difficult to get.

Virginia Environmental Endowment, Learn and Serve American, Toyota, and Virginia Power provided funding for the 1999-2000 school year. The following budget reflects the costs for the past year:

<i>Baywatcher</i> field trip	\$300
Classroom materials	\$200
Data collection equipment and water test chemicals	\$250
Marine Science Museum field trip	\$600
Trips to oyster float	\$480
Substitute teachers	\$900
Mathematics and science teacher (5% of time)	\$1,800
Total	\$4,530



**INTERVIEW WITH MARGARET DUFFEY**

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** I never intended to become a teacher. It just sort of happened. Now that I have been teaching for 27 years, I'm glad it happened. I wanted to be a mathematician with the space program. I changed my major to English after two years of college calculus and kept my minor in mathematics. The only English I ever taught was during my student teaching. I taught for four years in Westmoreland County before I got married and moved to Tidewater. I have been at W. E. Waters for 23 years and happily married that many years as well.

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** I work with a very energetic science teacher, Catherine Roberts. She has been the person who has inspired me to think out of the box and integrate mathematics and science. She and I have been on the same seventh grade team for about ten years now. We started off by having the students do science experiments in science class and then do the follow up calculations in math class. It kind of grew from there. Cathy would find more ways for me to use science in the math class and as a result, I have learned a great deal of science. When the Chesapeake Bay Foundation asked science teachers to volunteer to raise oysters, Cathy did not hesitate to get us involved. It has been a wonderful way to stimulate the students to do mathematics for a good cause.

**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** Every year I am delighted to see the students get into the oyster project. We have some students who have weak mathematics skills, low self-esteem, problems at home, etc. Many times it is these very students who become our "oyster groupies" and become very involved. Seventh grade students need a lot of hands-on experiences and this project really gives it to them. It helps to strengthen those weak math skills and definitely raises their self-esteem. (I wish it could help with the home life situation.) I cannot think of any unique or unexpected consequences resulting from the project. We expect the students to participate, have fun, learn more about mathematics and science and help to clean up the Chesapeake Bay, and all of these things do happen. Not all

students get involved, but then not everyone is interested in this project. The field trips are voluntary, the classwork is mandatory.

**Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on the student oyster restoration project? What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?**

**A:** I think I just answered this question in #3. My greatest lesson is that seventh grade students need to be involved. Science teachers have known this fact for more years than most math teachers. When students can see a reason for doing the mathematics, then they take ownership. When students can taste, smell, feel, and see the math, they find a reason for doing it. Sitting in neat little rows, working word problems out of a textbook is not the best way to invite students to love mathematics. By involving them in a project such as oyster restoration, and integrating math and science, the students are sort of tricked into doing the math because there is a real-world need to do it.

## INTERVIEW WITH CATHERINE ROBERTS

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** I have wanted to be a teacher since the second grade with a few side goals along the way. I of course wanted to be an astronaut in the 60's like almost every other kid, but I wore glasses and was a female so there was no hope. I was also interested in forestry, but at the time women only got desk jobs. Yuck! I have been very satisfied with the school to which I was assigned my first year teaching, and that is what has kept me in education. We are the best kept secret of Portsmouth; great kids, concerned parents, and friendly co-workers. I am drawn to research in the summers because science is also a true love.

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** We are involved in several environmental projects. Our philosophy is that students should be involved in real-world learning. Community partnerships prepare the students in the life skill of cooperation, which is necessary to accomplish goals. I believe that, rather than ending the lesson with the doom and gloom of what former generations have done to our environment, we should empower young people to be proactive: to get results rather than consequences.

Our partnership with the Chesapeake Bay Foundation put us in the right place at the right time. We were approached to become involved in this project because of our history in environmental work and our relationship with the staff of Chesapeake Bay Foundation. I sail on the Chesapeake Bay and am well aware of the environmental impact of man on this area. I jumped at the chance to "make a difference."

**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** The support of the community has been awesome. Student self-esteem soars as they realize they have been a part of a solution. The community reactions have validated our students as valuable members of that community.

**Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on the oyster restoration project? What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?**

**A:** Real-world learning is the most effective process. All students are successful. Students who do not experience success in the traditional classroom benefit the most. The rewards come from seeing the positive change in students who suddenly find they are capable.

## **CLIMBING THE LADDER FROM NINTH GRADE TO COLLEGE: A CAREER LADDER PROGRAM AT THE SCIENCE MUSEUM OF VIRGINIA**

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A. THOMAS and D. HAGAN  
*Science Museum of Virginia, Richmond, Virginia 23220*

The Career Ladder Program is one component of a greater youth development project conducted by the Science Museum of Virginia in partnership with Capital One Leadership Grants Program. This project is part of the Museum's strategic goals, driven by its mission to ensure that every Virginia student achieves science literacy leading to success in a career and the rewards of lifelong learning. This particular program, modeled in part on the National Science Foundation's YouthAlive initiative, provides guidance, support, and academic mentoring for middle and high school students, ages fourteen to eighteen from inner-city, low-income backgrounds; college attendance (or post-high school education) of participating children is the ultimate goal. The Career Ladder Program is in its third year of operation under the sponsorship of Capital One through its Capital One Leadership Grants Program. Capital One pledged "to improve the lives of our children today to support their development as leaders of tomorrow." Since its creation in fall 1997, approximately 44 students have participated in this project.

The Career Ladder Program provides support and encouragement for at-risk students and guides them to a new level of understanding of their full potential. The successful Career Ladder graduate will value high academic achievement, set a goal of earning a college degree, and ultimately gain successful employment—all within a culture that may not encourage such ambitions. The targeted student population has a high percentage of single-parent families, a high percentage of poverty and dependence on public assistance, and a high dropout rate from public education. For example, one high school in central Virginia served by the program has a 66% dropout rate for young males<sup>1</sup>. Of those families living in Richmond's East End, an area also served by the Career Ladder Program, 23% receive public assistance, 60% of the children live below the poverty line (85% of these children live in single-parent households), and 59% of the children live in single-parent homes<sup>1</sup>. These factors, especially in combination, may contribute to students engaging in, and suffering the consequences of, at-risk behavior; such as, failing and/or dropping out of school, substance abuse, teen pregnancy, and juvenile delinquency. By providing

<sup>1</sup> All statistics are courtesy of Richmond Public Schools. Specific values are for the 1996-97 year, the planning year for the project.



at-risk children with the tools and support needed for academic success, we hope to reduce the chances that these students will drop out of school and to increase the chances that they will enjoy fulfilling, well-paying careers.

In order to engage in continuous academic support for children as they move into middle and high school, the Career Ladder Program builds on the Museum's successful Science Connections Program (formerly titled "Science After School"), designed to engage elementary students in hands-on science lessons correlated to the Virginia Standards of Learning for science. Once they reach middle school, students have the opportunity to become Career Ladder Program volunteers. When these students reach high school, they can then move further up the "career ladder" to become paid high school interns. Together, the Science Connections Program and Career Ladder Program provide a vertical integration system of learning and mentoring.

In order to clearly develop and organize the program, we established four goals, each matched with objectives, appropriate activities, and evaluation tools. Evaluation is designed to follow the Evaluation Logic Model in reference to program goals, objectives, and activities. The Virginia Commonwealth University Survey Evaluation and Research Lab (VCU SERL), under contract with the Capital One Leadership Grant, conducts additional program evaluations that focus on student demographics and the influence of at-risk factors. This team has reported detailed data on attendance, but information on the program's effect on students' attitudes and behavior has not yet been released. This aspect of the study makes use of student survey responses dealing with such issues as decision-making, social competence, and relationship building.

### **Program Goals**

#### **(1) Provide workforce training**

**Objective:** Students will develop the necessary skills to obtain jobs and master the appropriate work habits and attitudes of model employees.

**Activities:** Students will receive skills training. On-the-job training will enhance the workshop activities and will consist of any of the following jobs: teacher's aide, completing office duties, serving as science activity presenters, and/or greeting and directing museum guests.

Evaluation Tools: Pre- and post-program test assessments administered for employability skills, as well as monthly on-the-job training evaluations.

(2) Provide academic and career guidance

Objective: Students will develop an educational commitment to learning; will graduate to the next grade level; will research, set, and plan appropriately for future career goals; and, will master the college application process.

Activities: Students will attend study skills workshops; will attend career and goal setting workshops; will tour colleges; will schedule their own tutoring time with in-house tutors; and juniors and seniors will receive SAT preparation training, as well as attend college application and financial aid workshops.

Evaluation: Student report cards monitored every nine weeks, in line with the school's academic reporting periods. Pre- and post-program career goal assessments administered.

(3) Provide basic life-skill training, including conflict resolution, prevention of substance abuse, and communication skills

Objective: Students will be prepared to make informed decisions as consumers; will develop skills to make appropriate decisions in social situations; will understand the physical consequences of substance abuse; and will make healthy life-choices to promote well-being.

Activities: Life-skill training components include: the personal and household budget, the employment application and interview, communication and relationships in the school and workplace, abuse prevention and health training.

Evaluation: Pre-and post-program assessments will be administered on life skills. Pre- and post-program surveys will be administered for attitudes on conflict resolution, substance abuse prevention, and health issues.

(4) Provide leadership experiences

Objective: Students will gain self-confidence and self-esteem; obtain in-depth topics; and act as mentors for younger students who participate in Science Connections and other museum programs.

Activities: Students will engage in volunteer activities in Museum programs, in family homeless shelters, in entrepreneurial projects for the development of web pages. The participating students will serve as members of the Capital One Leadership Grant’s Student Community Advisory Board.

Evaluation: Pre- and post-program assessment attitudinal surveys administered for leadership skills.

**Eligibility and Requirements**

Students must be at least fourteen years old for middle school volunteer positions, and at least sixteen years old for paid high school intern positions.

Students must be in good standing with a "C" or better. If a student earns a "D" in a class, they must obtain tutoring and achieve at least a "C" by the next reporting period.

Middle school students must commit approximately 180 hours a year (one to two hours per week) to the program and will receive an educational stipend of \$100 at the end of their service commitment. The paid high school intern component moves participants into a much more intensive commitment of 426-500 hours (average of three to seven hours per week) a year. The stipend translates into an hourly wage of approximately \$5.75 with a \$.25 raise for each returning year.

The budget breakdown is as follows:

	<u>1997-98</u>	<u>1998-99</u>	<u>1999-00</u>	<u>2000-01</u>
Capital One Grant (annual)	\$47,000	\$70,058	\$109,175	\$111,338
Student Participation	12	15	17	20

In addition to the Capital One Grant funding for a portion of certain staff salaries, Museum support includes staff benefits, some staff salaries and transportation costs, and most administrative costs (facility expenses, telephone, and overhead). Student rewards and benefits include free tutoring, on-the-job training, life-skills and leadership courses, college preparation workshops, museum passes, as well as cultural and social enrichment trips. For many students, going on field trips becomes a highlight of the program and, therefore, encourages them to continue their participation.

For the past two years, Career Ladder students have joined other students in youth agencies, also sponsored by the Capital One Leadership Grant, on informal educational trips to the U.S. Space Camp, the Kennedy Space Center at Cape Canaveral, Florida, and the Disney Youth Education Seminars in Orlando, Florida. We have had such good success with our students that they initiated a request to incorporate other youth leadership opportunities of their choice into the program. For the 1999-2000 school year, Career Ladder students provided seasonal science activities at selected family homeless shelters and other agencies. These projects gave students a chance to give back to the community and to serve as role models. Other student suggestions for 2000-2001 include starting a small web page development business (with the technical assistance of Capital One) and devising ways to earn extra money for additional field trips.

The Career Ladder program has reached an increased level of recognition through press coverage, including a forthcoming article in *Richmond Parents Monthly*, and through recruitment efforts. At first, we had to aggressively recruit children for participation; the reverse is now true with teens, parents, and principals initiating contact with the Science Museum and asking how they may participate in the program.

A goal of the Career Ladder Program is to make a positive impact on the lives of all participating youth. As mentioned before, many participating students face situations that may hinder their commitment to learning; it is our hope that they will overcome these factors with the constant encouragement and support of the Science Museum. The program began in 1997 with entering high school freshman, sophomores and juniors. In the 1999 and 2000 classes, a total of seven students graduated from the program with six out of the seven continuing on to college. Most importantly, all students who have participated have stayed in school and proceeded on to the next grade level. One specific example of the program's success is a student who was accepted to college after spending three years in the Career Ladder Program. Though he had

been ready to quit school in order to support his family, we encouraged him to stay academically focused during his time of financial and family stress. If asked what his motto would be for incoming Career Ladder students, this student replies, "It sounds silly or corny, but you will never know unless you try!"

Over the next year, we expect to serve twenty students (fifteen paid high school interns and five middle school volunteers). Future program designs include expanding the program to serve more inner-city students from low-income neighborhoods, as well as offering the program to students in low-income rural areas. Also, we will develop alternative career plans for those students who are not accepted to college.

A community institution targeting academic support of at-risk students can certainly take on a program like Career Ladder. An institution considering the establishment of a similar project should design a program that integrates mentoring, homework tutoring, SAT coaching, field trips, workforce training and leadership workshops, adequate funding, and volunteer support from community businesses. Actual employment for the high school students in a productive and effective work environment is also essential. In order for these various, and sometimes disparate, components to work well and efficiently, close coordination with school systems is mandatory; guidance counselors are powerful resources when it comes to implementing and sustaining such a program. And, of course, adequate funding is essential, both from the sponsor and from the host organization, in order to maintain staffing, overhead expenses, and supplies. Finally, full commitment to the program on the part of the host institution's leadership, as well as a dedicated, hard-working staff, are of utmost importance. ■

**INTERVIEW WITH ANGEL THOMAS**

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** I began my career at the Science Museum of Virginia in November 1993 as a part-time gallery educator shortly after graduation from Virginia Commonwealth University with a B. S. in Biology. I always loved science and this museum since I was a child. As there was an immediate opening, I thought to myself what a great opportunity to apply for—and it was! As the years went by, I progressed in the education department to a Science Center Program Coordinator (coordinating after school and summer class programs) to a Science Center Program Specialist, Senior (supervisor of after school, summer class, and Career Ladder Program). I originally aimed to have a career in field or lab work. As previously stated, there was an opening here at the Science Museum and it was a favorite place of mine.

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** No, the project was already a museum objective/goal. When the funding became available, the project was then given to me to develop, coordinate, and instruct because my supervisors thought I would do a good job with the program.

**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** Yes, of course. The program is now in its third full year of operation. The unexpected consequence was the program's success. It has certainly flourished since its beginning during 1997-1998 in more ways than one:

- a. Program Recognition In addition to the Virginia Math and Science Coalition award, the program has gained recognition in other ways. The program has been appointed as an Honorary Member of the Business Faculty for Richmond Public Schools for the supervision and instruction of the Cooperative Office Education student(s) on the job.

Students, parents, and schools call frequently now in hopes of us recruiting students and expanding the program. Also, *Richmond Parents Monthly* magazine will be publishing a forthcoming article.

- b. Program Graduates We have had six seniors since the program started three years ago and all of our students have graduated and gone on to college.
- c. Number of students served increased Went from serving twelve students to the current seventeen students.
- d. Number of Program Staff increased Started out with one part-time staff member; now have one full-time program coordinator and one part-time employee (a former Career Ladder Program graduate and now in college).
- e. Collaboration among similar youth agencies Due to our funding through Capital One, we have managed to build strong relationships and collaborate with other youth serving agencies from the Richmond area. We meet monthly to follow through with our Capital One Leadership Pledge, “ We pledge to improve the lives of our children today to support their development as the leaders of tomorrow.”

**Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on the Career Ladder Program? What is the greatest benefit you see coming to students through their engagement on this program?**

**A:** The greatest and hardest lesson that I have learned is that sometimes the Program staff may be the only support that these students have to inspire them to succeed in school and set career goals. Some of our students do not receive these encouraging messages from home. In any case, the Career Ladder Program seeks to encourage students that “they can beat the odds and excel.”

The greatest reward that I have gained through working with the Career Ladder Program is when my students succeed and beat the odds in many ways (academically, socially, emotionally). Plus, I am able to give back to the community in which I grew up.

## ACHIEVING SCIENCE SOL WITH A HANDS-ON APPROACH

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J. N. GRANGER

*Sweet Briar College, Sweet Briar, Virginia 24595*

Sweet Briar College is a small, highly selective, four-year liberal arts college, located in the foothills of central Virginia. As a women's college, Sweet Briar has always felt very strongly that it belongs at the forefront of education for women in *all* fields, but especially those, such as the sciences, which have been traditionally viewed as male domains. Sweet Briar's science faculty believes that the best way for students to *learn* science is for them to *do* science. To support the mission of providing Sweet Briar students with a laboratory-rich science education, the College has invested, over the last decade, significant resources and has been successful at attracting notable outside support for facilities, equipment, and research. The impact of these efforts has been striking: since 1992, enrollments in science courses at Sweet Briar have increased by 42%, while the percentage of degrees awarded in the sciences has increased by 75%. Of our entering students, 36% now list science as their first academic interest, compared to just 18% of freshmen women nationally [1]; and, 35% of Sweet Briar students now graduate with science degrees, compared to just 16% of women graduates nationally [2].

In our project, "Achieving Science SOL with a Hands-On Approach," we wanted to use Sweet Briar's strong science program and the newly developed materials from the Women in Chemistry Consortium (WCC) to make a local impact in our region of central Virginia. Through making summer research internships available for local high school students, Sweet Briar science faculty began a dialogue with area science teachers. In conversations with area teachers over the following months, Sweet Briar science faculty members realized the need for creating better connections between the College's resources and the area school systems. The Department of Chemistry at Sweet Briar College has had an on-going interest in K-12 science education, witnessed by its strong participation in the WCC, as well as its leadership role in a follow-on project, *New Pathways to Chemistry*. These projects were multi-college collaborations, funded by the National Science Foundation, the Dreyfus Foundation, and the duPont Foundation, to create materials for use first in college and later, in high school chemistry courses. Our project would take these materials and implement them in the area school systems.



Our project serves teachers in the central Virginia area, including public and private schools in the city of Lynchburg and six surrounding counties; these systems are within the immediate area of Sweet Briar College. Our summer workshops are held in the Guion Science Center at Sweet Briar. On-campus housing in the College dorms was provided to teachers who requested it. Large group discussions over lunch were held in the College cafeteria.

The *New Pathways to Chemistry* laboratory modules, the basis for this project, were specifically designed to be effective for all types of students, especially girls, young women, and minorities. These students may not have had opportunities for curricular or extra-curricular use of scientific equipment and might, therefore, feel less comfortable with a traditional science laboratory exercise [3]. When students are uneasy with the process, they are much more likely to feel alienated and to be “turned off.” By using materials that are familiar to the students, and by asking questions that are relevant to real life, the modules attempt to minimize the effects of prior experiences or lack thereof. The open-ended nature of the modules is also extremely valuable for encouraging women and minorities to view themselves as scientists. The active involvement of the student in the design of the experiment, in the determination of which observations to make, and in the making and interpreting of those observations, makes the student a practitioner of science—in other words, a scientist. The student succeeds at doing science and, is therefore more likely to try more science, since nothing builds self-confidence like success.

Our project’s goals are founded on the previous work of colleagues involved in the WCC. Their goals, like ours, are to “extend to high school teachers the inquiry-based chemistry laboratory curriculum which has been successful attracting and retaining young women in chemistry and to establish a collegial environment for college professors and high school teachers to learn from each other.” Additionally, we saw the opportunity to attract talented middle school teachers into the program in order to begin to draw the attention of their students, impressionable young people, toward science. We were especially interested in reaching girls and minorities who traditionally do not see themselves as scientists. By participating in this project, area middle school teachers were provided a stimulating work environment in which to modify the high school chemistry experiments to best meet their own physical science Standards of Learning.

This project contains three essential parts: an intensive laboratory course for pre-service undergraduates; a two-week intensive, collegial laboratory experience for in-service teachers;

and, a follow-up program which encourages and supports the in-class use of the laboratory approach. This serves to help pre-service teachers see modules in action, and aids the in-service teachers by providing needed assistance during lab time. Our objectives are to:

- Increase opportunities for central Virginia's school children to utilize inquiry based, hands-on learning in areas of scientific inquiry and experimentation, thus enabling them to learn more about modern science and its methods, and exciting them about scientific investigation.
- Positively affect teacher attitudes toward doing experimentation in the classroom.
- Increase the amount of time teachers spend doing experimentation with children in the classroom.
- Provide the teachers with a curriculum that supports their classroom content using an inquiry-based, hands-on approach.
- Positively affect pre-service teacher attitudes toward science education.
- Create a network of science teachers in the region and link science teachers with resources at the College.

In the summer of 1999, we conducted two, two-week workshops. The first workshop was conducted for a group of seven undergraduate students from three central Virginia colleges. The second workshop was conducted for 26 in-service teachers from our local area. The lab experiments that we used were part of the *New Pathways to Chemistry* curriculum. The same experiments were done in the in-service teacher workshop as were done in the pre-service teacher workshop. Our workshops began each day with a brief introduction on the subject. Lectures and whole group instruction were kept to an absolute minimum. The college faculty instructors modeled their teaching to encourage the teacher participants to learn and experience the new material in a hands-on way. Participants were engaged in intense morning laboratory exercises. The experiments that were taught were based on real-world applications of chemistry and were usually multi-session lab modules. In the two-week session, the participants completed twenty of the *New Pathways* modules, or variations thereof.

The workshop lunch hour consisted of small and large group discussions. Topics were chosen to complement the subjects of the morning exercises. A set of open-ended questions was posed at each lunch table and the participants seated at the table used the questions to guide discussion. After lunch, the whole group would meet to talk about what was learned and discussed. Subjects for lunch discussion included: safety, instrumentation, science out of the

classroom, and building partnerships. Notes from the small group discussions were taken at each lunch table and are available on our web site.

The afternoon hours of the workshops were less structured. Teachers were given a variety of resources including computers, lab equipment, chemicals, and facilities for small group meetings, in addition to the full attention of the college faculty and teaching assistants. Teachers were encouraged to continue lab work, testing new ideas, modifications or extensions of the morning experiments. Teachers from the same school or school district were also encouraged to meet together in small groups to talk about curriculum planning and implementation. We also encouraged the teachers to use our computer labs, including word processing and internet access, to create materials based on their morning lab experiences for student use.

Our project offered participants two additional types of support. Materials and supplies were offered to the teachers to give them the requisite resources they needed for successfully implementing the experiments in their classrooms. Teachers primarily purchased lab supplies, such as beakers, hot plates, test tubes, pipettes, dropper bottles, wash bottles, storage bottles, petri dishes, graduated cylinders, and the like. Additional funds from the Gwathmey trust provided us with a set of sixteen Educator Spectrophotometers. These instruments were used in the summer workshops to introduce the teachers to modern scientific instrumentation. Approximately one and a half days of the workshop involved the use of the spectrophotometer. During the academic year, the instruments were out on loan according to a rotating schedule of the teachers' design. The course instructors and the teachers worked together to move the instruments around the region to the various schools throughout the school year. All 26 of the teachers signed up at the end of the workshop to have the spectrophotometers brought into their classrooms during the upcoming academic year—some teachers requested all sixteen spectrophotometers at the same time!

During the academic year of 1999-2000, teacher participants were involved in implementing the experiments in their classrooms. Three of the pre-service teachers assisted in implementation for at least part of the academic year. One of the pre-service teachers completed 120 hours of classroom visitation.

In an end-of-workshop questionnaire, teachers responded with comments such as:

“I feel more like a scientist and have gained [an] understanding of how to help students link their science experiences in school to outside the classroom and other subject areas to increase student interest and motivation.”

“I have had the opportunity to become more confident using equipment such as the spectrophotometer...”

To the evaluation statements, teachers were asked to respond using a 5-point scale: 5=strongly agree, 4=agree, 3=neutral, 2=disagree, 1=strongly disagree. All 26 teacher-participants responded with “5-strongly agree” to the following two evaluation statements: “I would consider taking another summer workshop from these instructors” and, “I would recommend these instructors/this program to other teachers in my school.”

We are still receiving data from the teachers regarding the extent to which they were able to incorporate the experiments into their classes. Brian Caldwell reports that he worked with the new chemistry teacher at Buckingham County High School implementing three of the course modules. Brian stated, “The information and activities were useful. We had a new chemistry teacher; he found the activities a great help in planning course content.” Marilyn Buck, in the fall semester, asked her tenth-grade chemistry students to write us a note regarding three of the experiments they tried that semester. Katie Kirkwood reported, “[The spectrophotometer lab] helped me understand the ideas of transmittance and absorbance more clearly. It was easier to see the differences than it was to understand it by reading it out of a textbook.”

On the same evaluation, teachers were asked to respond to this statement: “I intend to do more hands-on science activities in the classroom than I have done before, increasing the amount of time my students have for inquiry-based learning”; the response was an average of 4.4 on the 5-point scale.

Free-form comments from the teachers include: “I really hope additional workshops for physical science eighth - sixth can be developed”; “Before I came here, I had *only a few* experiments to do with my students and now I feel that I can do at least one a week”; “I would

be interested in seeing more programs like this especially in the upper-elementary sciences. I would be interested in participating in such a workshop.”

The interim report from the College and University Resource Institute (CURI) evaluators was also very encouraging to us regarding the impact of the project. Their conclusions were drawn from a site visit during the July workshop and a review of all of the pre- and post-workshop questionnaires. In this report, the evaluators state, “These responses [with respect to the principal outcome of the project] should assure the staff that the program was successful.” With respect to the pre-service workshop in particular, the evaluators stated that, “primarily, [the workshop] changed the participants’ attitudes and made them more positive toward science.” It seemed to the evaluators that we were also successful in meeting our goal of creating more connections between the local schools and the College. The evaluators stated that, “... high ranking [to a set of four questions regarding setting and planning] responses indicate a real strength in the program in the areas of instructor skills and partnerships with the participants; ... This adds a permanent dimension to the project whether or not more funding is acquired.”

In our end-of-workshop discussions with the participating teachers, we noted the strong opinion among these participants that more needed to be done in terms of “covering more SOL.” There was an especially strong indication that interest in continuing education in science was highest among the lower grade teachers (in this group fourth through sixth grades). We acted on this recommendation in designing our 2000-2001 SCHEV-Eisenhower Professional Development Workshop—an extension of the 1999-2000 project—into the fourth - eighth grades. In our 2000-2001 Eisenhower program, we are including experiments in chemistry (based on the WCC modules, adapted for the lower grades), biology, and physics.

One of our 1999-2000 teacher participants was a special education teacher. Most of the participating teachers have mixed-ability classrooms. While the hands-on nature of the science experiments is a learning strategy that works well with children who need special education, we did not address this issue in our workshop. We, and our outside evaluators, consider that this is an area of science education that could be addressed more specifically in a future program.

The federally funded Dwight D. Eisenhower Professional Development Program (Eisenhower), through the State Council of Higher Education for Virginia (SCHEV), supported our project. We received an Eisenhower grant in the amount of \$50,417 to fund our project. In addition, we received an award of \$12,000 from the Gwathmey Memorial Trust that provided

our teachers with sixteen spectrophotometers, used for the summer workshops and taken into the classrooms during the 1999-2000 school year. The project cost was \$1,527 per participant, excluding the Gwathmey funds.

Teacher participants received a \$500 stipend for their completion of the two-week summer workshop. No additional compensation was given for their academic year efforts. Teachers also received a \$400 budget for the purchase of supplies needed to carry out the implementation of the experiments in their classrooms.

The in-service teachers also received continuing education credits from Sweet Briar College. Pre-service undergraduates received a \$300 stipend for completing the two-week workshop. They were also eligible to receive undergraduate credits (as internship credits) for participating in the academic year implementation aspect of the project.

The request to SCHEV was made in November of 1998 for our Eisenhower grant. Collaborating faculty in chemistry and biology designed the project (Jill Granger and Robin Davies); the grant was written with input from Sweet Briar's Department of Education (Jim Alouf) and the College's Director of Foundations and Government Grants (Tom Loftus). Project planning began in September of 1998 with meetings of the Sweet Briar project team and representatives from the area high school departments of science and administration.

In addition to face-to-face meetings with the area teachers and administrators, we also mailed our proposed workshop curriculum to area middle school teachers to seek their opinion on the appropriateness and applicability of the experiments to the science content taught in grades seven and eight. By adapting the high school level chemistry experiments to also meet the Standards of Learning for the middle school course in physical science, we were able to serve more teachers in our area.

In the initial stage of the project, we had no budget for paying the pre-service student participants a stipend: we envisioned that the students would sign up for "free" education, tuition-waived. When, after months of heavy recruiting, we had no pre-service participants enrolled, we surveyed the education students at Sweet Briar. We learned that they had a need to make money during the summer to meet their academic year expenses. Based on this information, we re-designed the budget to provide the student participants with free on-campus room and board (partially paid for by the grant and heavily subsidized by the College) and a

modest stipend. Once we could cover the out-of-pocket expenses for the students, we began a second advertising campaign on the three college campuses.

In-service teachers were genuinely grateful for the \$500 stipend they received for the workshop. They were absolutely thrilled to receive the additional materials and supplies for academic year implementation. This level of support has given us a generally high level of teacher cooperation for the entire project. Teacher participants are also very concerned with earning recertification points for their participation from their school systems. This issue has been a complicated one for us to deal with because of the number of different participating schools. We have taken to providing the teachers with a certificate of completion and assigning them one continuing education credit (CEU) for each hour in the workshop. Thus the two-week workshop, which met from 9:00 to 3:00 each day, had 60 CEUs attached to it. Assigning this type of credit was a new venture for this traditional liberal arts college; it required us to work with the President's Office and the Registrar to get the policy and paperwork in place. By giving continuing education credits across the board, the individual school systems can interpret the teacher's participation to best fit their local recertification guidelines. Typically, the teachers received six out of nine points needed (or sixty out of ninety points needed) for recertification. For teachers who do not have a master's degree, it was important for us to note on their certification that the workshop was a science content course in order for them to get recertification credit for science content.

SCHEV, CURI, and the Sweet Briar College project team evaluated the project. SCHEV sent a site visitor to the workshop for one day. This visitor interviewed participants and mingled in the labs observing the teachers' activities. She also sat in on our lunchtime discussion forum. Two outside evaluators were employed by the budget of the project. These evaluators were hired because of their experience evaluating such projects. The CURI evaluators made a one-day visit to the workshop. They also conducted a pre- and post-workshop survey of the teachers regarding their attitudes toward making changes in their classrooms and their views of education reform. The SBC project team administered their own pre- and post-workshop questionnaires to the undergraduate group and to the in-service group assessing multiple aspects of the project from the specific (rating each individual experiment) to the general (rating the overall quality of the experience). In all, the teachers responded to over fifty questions. All of the information obtained by the SBC faculty was forwarded to the CURI evaluators to be included in their summative report. At the end of the workshop, teachers were also given a short form for reporting on activities conducted during the academic year.

At the end of the academic year June 2000, teachers were mailed a final project questionnaire written by the SBC faculty. They were asked to return it along with their academic year activity reports. Approximately half of them have been returned. These will also be forwarded to the CURI evaluators for inclusion in their summative report.

We imagine that the basic structure of this project could be adopted for almost any situation. Key elements include a dedicated faculty team with expertise in the content area and patience for the managerial issues that arise, a supportive institution to both host and support the program, and a willingness on the part of area schools to make the project known to their teachers. ■

## References

- [1] *The American Freshman: National Norms for Fall 1997*, The American Council on Education and the University Of California at Los Angeles Higher Education Research Institute.
- [2] *Science and Engineering Degrees: 1966-94*, NSF 96-321, National Science Foundation, Arlington, VA, 1996.
- [3] S.V. Rosser, "Female Friendly Science: Including Women in Curricular Content and Pedagogy in Science," *The Journal of General Education*, 42 (1993) 191-220.



**INTERVIEW WITH JILL GRANGER**

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** I went to Butler University, in Indianapolis (near my hometown) and got my Bachelor's degree in chemistry. During the summer before my senior year, my senior undergraduate year, and the summer following graduation, (fifteen months in all) I worked as a co-op student at Merrell-Dow Pharmaceuticals. I was doing research on potential anti-viral compounds in search of a drug to arrest the action of the enzyme reverse transcriptase. I had also done undergraduate research at Butler in previous years at the Holcomb Research Center (an independent lab on campus). In addition, I had worked with several faculty members in the chemistry department and the College of Pharmacy doing research projects. I liked doing these research projects and enjoyed working with the scientists. My dad encouraged me to get the co-op position at Dow,—which turned out to be the primary reason I considered going to graduate school.

I went to graduate school primarily to do anti-cancer research—specifically in the area of "rational drug design." I had considered that much of what I had done at Dow was fairly irrational (get a panel of drugs, test them all, look for trends, find similar compounds, test again...). I wanted to get a better understanding of drug action and structure relationships. To a lesser extent, I wanted to go to graduate school to gain the credentials that I would need to write a textbook (writing has always been one of my interests) for high school chemistry. I went to Purdue, slightly to the north.

I did cancer research at Purdue and was a National Institutes of Health (NIH) Cancer Center Fellow. My research involved a variety of techniques including manual and robotic synthesis, high field NMR, and molecular modeling and computational chemistry. I also received a scholarship called the GE-Purdue Foundation Teaching Incentive Award to help support me as a graduate student and encourage me to consider a teaching career. At the end of my stay (1988 -1993) at Purdue, I realized that teaching has always been my real passion and interest—I had done most of the requirements for teacher licensure while I was at Butler—and so I sought a faculty position. I was lucky enough to get hired at Sweet Briar (and had an offer at another college as well). (Maybe someday I'll get around to doing that post-doc.)

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** I've never been involved in a teacher education program before. I would say that my interest in the project was stimulated by a National Science Foundation (NSF) speaker that I heard at the 1998 Council on Undergraduate Research meeting in Los Angeles. He was basically reporting on NSF's statement "Shaping the Future" and spoke passionately about "cradle to grave" education. It was very inspiring. I also went to a workshop at that conference on Juniata College's Chemistry Van project. I could see a lot of similarities between the area of Pennsylvania that Juniata serves and this part of central Virginia. I was really fired up by the idea of a college serving as a resource to area schools and their teachers. When I got back to Sweet Briar College, my colleagues were very supportive of me moving my research efforts in this direction. I guess having four kids of my own (now ages 0.5, 4, 6, and 8) - keeps me energized about teacher education. I am also a member of Project Kaleidoscope's Faculty of the Future, a group of college faculty leaders. This organization also encourages personal growth and professional development. They are a great supporter of college/school partnerships and faculty involvement in change and reform.

**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** The first thing that comes to mind is the Virginia Math and Science Coalition (VMSC) award. That was quite unexpected! I guess the amount of publicity we have received in general has been unexpected—certainly we've gotten more press-time on this project in the year and half we've been doing it than I got in all of the eleven years I was doing cancer research! In general, that's the great thing about working with the teachers and the schools. People in the schools are really grateful for everything you do for them—no matter how small an effort it may be—and you get instant feedback. It's a great feeling to know that what you're doing is making a difference to people. Not to say that cancer research doesn't make a difference to people's lives but... you just don't get the same kind of feedback in the same time frame.

**Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on “Achieving Science SOL?” What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?**

**A:** With respect to personal rewards - see Question #3. The greatest benefit I see is that we get to bring teachers together to work on improving science education and we get to allay a lot of their fears in that regard. It still surprises me how anxious many of the teachers are about “teaching science.” When we bring them together, they gain a lot of strength from their peers, who may be less anxious, and the environment and resources that we are able to provide.

## **THE SONIA KOVALEVSKY HIGH SCHOOL MATHEMATICS DAY**

E. G. D. JONES

*Norfolk State University, Norfolk, Virginia*

Since 1985, the Association for Women in Mathematics (AWM) has received grants to support Sonia Kovalevsky (SK) High School Mathematics Days at colleges and universities throughout the country<sup>1</sup>. At first, grants to AWM were from the Alfred P. Sloan Foundation and the National Science Foundation, but in more recent years the grants have been from the National Security Agency. In turn, AWM has awarded more than 125 grants of up to \$5,000 each to universities and colleges. Historically Black institutions and women's colleges are particularly encouraged to apply. The selected institutions are requested to secure additional funding in support of the program from local sources. Thus, colleges and universities throughout the country run Sonia Kovalevsky High School Mathematics Days. These individually funded programs are intended to promote an interest in the mathematical sciences among high school females in grades nine through twelve by introducing them, and their teachers (of both genders), to exciting applications of mathematics, and thereby encouraging them to consider mathematics as an appropriate field for women to enter.

The local program administrator, Dr. Eleanor G.D. Jones, first applied for an AWM grant in 1994; this grant funded the first SK High School Mathematics Day at Norfolk State University. This first Mathematics Day was so successful that AWM invited Jones to again apply and responded favorably to that application, as well as to subsequent applications. The mathematics department at Norfolk State has a truly integrated faculty of African-Americans, European-Americans, Asian-Americans, and foreign nationals with no one group having a majority. Under the leadership of the department head, Dr. Phillip McNeil, staff and faculty members of the Mathematics Department always assist with the program.

The program at Norfolk features motivational talks, workshops for students, team problem-solving competitions, workshops for teachers, lunch with a discussion group, and a career panel. Each teacher and student receives a certificate of participation; certificates

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<sup>1</sup> Sonia Kovalevsky was the first woman to earn a Ph.D. in mathematics from the University of Stockholm in 1874.

acknowledging outstanding achievement—are also presented to teams of students that excelled in the competitions.

The team competitions alleviate mathematical anxiety in participants as they experience the enjoyment of solving mathematical problems with the collaboration of others. The calculator workshops enhance the participants' proficiency in the appropriate use of the calculator. Moreover, the latest models of scientific and/or graphing calculators are used which means participants are introduced to the most current adaptation of calculator procedures to mathematical subjects.

With only one exception, the luncheon panel always consists of women from different professions who discuss their respective use of math and the opportunities which math provides. Professor James D. Reid of Wesleyan University in Connecticut is the only man to have been a High School Day panelist. Since he has been an inspiration, as well as the Ph.D. dissertation advisor, to several women now working in the mathematical sciences (including Jones) the presence of this distinguished and scholarly gentleman was an asset.

The population served by our project usually consists of 160 to 180 female high school students and twenty to thirty mathematics teachers from high schools in the Tidewater region of Virginia. We serve the cities of Chesapeake, Norfolk, Portsmouth, and Virginia Beach—all less than a forty-minute drive from the University. School participation includes ten public high schools, one private high school, and one Catholic high school.

Local donors often provide prizes for participants. At the first SK High School Day, a Texas Instruments promoter donated eleven TI30 calculators to a workshop presenter. These calculators were then awarded to those excelling in the competitions. A recent keynote speaker gave fascinating geometric puzzle key rings as souvenirs for each participant.

Writing the funding proposal to AWM for the High School Day is the first step in the organizational process. Responses to proposals have resulted in funding from as low as \$1,800 to as high as \$4,600. The amount of funding impacts decisions on who will be involved in the program. For instance, a female mathematician from the National Security Agency usually is available without cost to our program, but budgetary concerns dictate the level of honoraria to be offered to potential speakers.

When one of the larger funding amounts was available from AWM, the following proposed budget was submitted:

Food (approximately 200 persons)	\$2000
Registration/Printing	\$200
Telephone	\$25
Postage/Faxing	\$25
Photography	\$60
Travel/Lodging	\$1,400
Honoraria	\$800
Total	\$4,510

Most of the postage, faxing, and telephone costs are absorbed by the Mathematics Department at Norfolk State University, but these items are budgeted in case it might be necessary to use these services off-campus. When smaller grant amounts are received, honoraria are eliminated, travel and lodging expenses are decreased or eliminated, and the amount budgeted for food is decreased.

After receiving AWM's approval, brochures announcing the event are sent to the area high schools approximately two months before the scheduled program date. The brochure includes the program of the High School Day. At each school, the principal or mathematics chair is asked to personally select a mathematics teacher to be a liaison. Then the registration forms and brochures, along with picture posters, are sent to the liaisons to be displayed in the appropriate classrooms. Weekly telephone contact is made with the liaisons until the desired quantity and quality of applications are received. Every school that decides to have a student participate also must have at least one mathematics teacher participate; this condition is stated in the announcement brochure.

During the past Sonia Kovalevsky Day, an information packet sent by AWM was extremely helpful in the planning and the execution of the program. For the problem solving session, use was made of some of the problems in the packet. Also, the AWM questionnaire was used for evaluation. Additionally, two very timely and appropriate booklets, *Careers that Count*

and *Profiles of Women in Mathematics*, were provided by AWM for inclusion in the folder prepared for each participant.

The program concludes with each participant responding to the evaluation questionnaire in the information packet received from AWM. The feedback is quite useful in identifying the strengths and weaknesses of the program; we rely on these responses to plan future programs. Overall, the most important outcome is increased student awareness of the role of mathematics in many occupational endeavors, and that this is a field in which women can certainly take part. ■

**INTERVIEW WITH ELEANOR JONES**

**Q. What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

A. After graduation from high school, I entered Howard University to prepare to be a public school mathematics teacher. I received my Bachelor of Science degree with a major in mathematics and minors in both physics and education. Howard then offered me a fellowship, so I stayed another year and received my master's in mathematics.

A few months later I became a science and mathematics teacher at B.T. Washington High School in Norfolk. During my second year of employment, I was married to Edward A. Dawley, Jr. and the following year gave birth to a son. My second son (now deceased) was born eighteen months later.

When my second son was ten months old, I accepted employment as a mathematics instructor at Hampton Institute (now Hampton University). After being there six years, the academic dean very strongly indicated that I should do further study. My marriage was disintegrating, so my husband discontinued his law practice in Virginia and moved to California, while my two sons and I went to Syracuse where we lived for four years until I received the Ph.D. degree in mathematics from Syracuse University.

**Q. Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

A. Dr. Mary Gray, a professor of statistics at American University as well as a practicing attorney and long-time executive of the Association for Women in Mathematics, provided the stimulus by asking me to write the proposal for funds for a Sonia Kovalevsky High School Day.

**Q. Have there been any unique or unexpected consequences for you resulting from your project?**

A. The appeal of mathematical problem solving was greater than I expected and more diverse than I anticipated.



**Q.** Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on the Sonia Kovalevsky High School Day? What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?

**A.** It has been rewarding to have convinced some students and teachers that mathematics can be an enjoyable and entertaining endeavor.

# DIVERSITY EDUCATION FOR PRE-SERVICE SCIENCE TEACHERS

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D. R. STERLING

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## **Introduction**

Themes of diversity and equity are included in the science methods courses for all pre-service teachers enrolled in the Graduate School of Education at George Mason University. One of our goals in the science methods courses is to raise pre-service teachers' awareness of diversity among scientists, as well as among their own students. This knowledge is then incorporated into classroom planning and teaching. Our definition of diversity is inclusive, rather than exclusive, and includes ethnicity, gender, and special needs. While a few teacher education courses focus entirely on diversity and equity issues, the underlying belief is that diversity and equity awareness should be included in all teacher education courses.

## **Context**

### **Community and Participants**

George Mason University, located in northern Virginia and adjacent to Washington, D.C., has 25,000 students. It is a public institution that offers over 100 academic degrees at the undergraduate, master's, doctoral, and professional levels. The teacher licensure programs are five-year programs that lead to a Virginia teaching license and a master's degree. The pre-service teachers have already completed their bachelor's degree. Indicative of the highly mobile population in the area, over 75% of the pre-service teachers have earned their undergraduate degrees from other institutions.

### **Program**

In the pre-service teacher education programs at the elementary, middle, and high school levels, two science methods courses are required—a basic and an advanced course. Diversity and equity activities are taught in both courses: awareness and information-gathering activities take place during the basic course, while application to planning and teaching takes place during the advanced course. Each course is three graduate credits and includes hands-on and inquiry-based strategies for teaching biological, physical, and earth science. The courses *require* pre-service teachers to plan curriculum materials that meet state [1] and national standards [2, 3]. The

science education courses provide a unique opportunity to challenge all pre-service teachers to investigate diversity and create science lessons for all children.

### **Support**

The diversity and equity activities for the pre-service science methods courses were created with no outside support or funding. The science educator who taught the courses planned the activities and included these themes in the classes.

### **Diversity and Equity Activities**

The activities in which all pre-service teachers in science methods courses participate fall into three categories: awareness, information gathering, and adapting lessons.

#### **Awareness**

To focus the pre-service teachers on their perceptions of who scientists are and what they do, the teachers participate in two activities on the first day of the course: draw a scientist and minority scientists.

##### 1. Draw a Scientist

Each pre-service teacher is given a blank sheet of paper and asked to draw a scientist in approximately ten minutes. When all of the pictures are complete, the pictures are shared in small groups. The whole class then brainstorms to come up with a list of characteristics they think would be included in their students' drawings of scientists. This list usually includes characteristics such as, white male, lab coat, glasses, pocket protector, frizzy hair, and "nerd." When the list is complete, a poll is taken to find out which of these characteristics are in the teachers' own drawings. Most teachers find that their own drawings portray these same characteristics. The discussion for the day ends with these unanswered questions: Is this really who scientists are? Are these the impressions we want children to have? These questions are then linked to their scientist interview assignment and the promise of further discussion.

##### 2. Female and Minority Scientists

To focus on minority scientists, the students individually brainstorm to create a list of female scientists and a list of ethnically diverse scientists. Typically, the pre-service teachers, all of whom have college degrees and are in a graduate teacher licensure program, can name only one female scientist (Marie Curie) and no ethnic minority scientists. This simple activity raises their awareness of their lack of knowledge in this area. To expand the list to scientists with

disabilities, information about Stephen Hawking, one of the most brilliant living scientists, is shared with the class. Hawking continues his research in theoretical astrophysics even though he has amyotrophic lateral sclerosis, is confined to a wheelchair, and can no longer speak. These activities are then linked to the female and minority scientists research assignment.

### **Information Gathering**

In order to increase the teachers' knowledge of diversity among scientists and to expand their understanding of what scientists do, they conduct a series of short research assignments that are shared with the class.

#### 1. Female and Minority Scientists Research

Each teacher researches one female scientist and one ethnic minority scientist. Lists of names are provided, though the teachers are not confined to the scientists on the lists. Research is usually conducted using encyclopedia-type resources or the internet. The teachers return to class with one-page drawings and/or essays about the scientists they investigated. These reports are shared in small groups so that the teachers may further expand their own knowledge of female and minority scientists.

The individual pages are taped together to form two quilts. Each quilt is labeled as minority scientists or female scientists and hung on the wall. Most of the pre-service teachers choose to write reports instead of drawing a picture, chart, or diagram which leads to a discussion about the diversity in their learning styles and hence, in their teaching styles and the learning styles of their students.

#### 2. Scientist Interview

Since many people who are not scientists have misconceptions about who a scientist is and what a scientist does, the teachers in our elementary and middle school programs interview a scientist, engineer, or a person working in a technical field. The person interviewed should have at least a four-year science or engineering degree and be employed as a scientist or engineer. Someone with whom they have a personal connection, such as a spouse, parent, adult child, neighbor, or friend, is preferable. The thirty-minute interview with a scientist or engineer of their choice is summarized in a report (minimum of three pages) using a question and answer format. Teachers are encouraged to conduct the interview at the scientist's workplace. In addition to questions of their own, they ask a common series of questions so that information can be compared and analyzed in class.

### 3. Gender Equity Research

To raise gender sensitivity, videotape from *Dateline NBC* that features Myra and David Sadker and their research on gender bias is shown in class [4]. Having teachers see actual examples of unintended gender bias in the classroom has completely changed the level of discussion by pre-service teachers from denial to amazement that this really happens. At the conclusion of the videotape, the teachers break into animated discussion as they analyze the report for bias. They discuss who was called on in class and how this could be monitored for equity in their own classes. Additionally, they focus on asking follow-up probing questions as a strategy that should be used for all students, not just boys. To conclude the discussion, practices shown to reduce gender bias, such as cooperative learning, single-sex classes, or small groups, are explored.

### **Adapting Lessons**

After creating lesson plans to teach science specified by the Virginia Standards of Learning [1] to "typical" students, the lessons are adapted to meet the needs of students with special needs. The goal is to have the pre-service teachers construct a culturally and gender sensitive learning environment where children feel free to explore and learn. The learning environment should provide opportunities for children to learn diversity-related science content, as well as to learn about role models. The topic of role models does not have to be forced; many opportunities for learning about diversity occur naturally within the subject matter. Also, attention should be paid to the individual learning styles of each child.

#### 1. Planning Lessons

The pre-service teachers randomly draw four student case studies, one from each of four categories—English as a second language, learning disabled, physically handicapped, and gifted and talented. They then conduct research to learn more about meeting the needs of their case-study students. The pre-service teachers learn about their students, plan lessons so that the content makes use of examples with which students can identify, and plan units that are taught in ways that take advantage of the students' strengths as learners. Their previously planned lessons are adapted to their four special needs children, emphasizing abilities rather than disabilities.

#### 2. Teaching Lessons

In pairs, the pre-service educators teach a standards-based lesson, while at the same time addressing the needs of diverse learners, to their fellow classmates. When teaching the lesson, they first give an overview of where the lesson fits into the unit, and then teach the lesson as they

would to children. Lastly, they share the strategies they have demonstrated and show how these meet the diverse needs of learners. The entire lesson is videotaped.

### 3. Videotape Analysis

The pre-service teachers analyze the videotape of themselves teaching model lessons to students with different needs. They identify effective teaching and areas of growth.

### **Evaluation Process**

The pre-assessment and summative projects show that pre-service teachers can make great gains in knowledge about teaching and learning for female and minority students and that they are able to demonstrate these new skills. Since these projects are part of a graduate program, pre-service teachers are graded on the quality of their projects. This lets us know how we are doing each semester.

As part of the on-going improvement process, all of the pre-service teachers evaluate each assignment, as well as the course, and make suggestions for improvement. Since these assignments have been used for at least five years, there are few suggestions for improvement and they remain highly rated as valuable learning experiences.

### **Outcomes**

#### **Awareness Activities**

Pre-assessment shows that most pre-service teachers are not able to identify female and minority scientists, nor do they know how to adapt lessons for female and minority students. By the end of the science methods courses, all pre-service teachers are able to discuss a variety of scientists, as well as demonstrate how to adapt lessons to meet the diverse needs of learners. The "draw a scientist" activity helps the teachers understand their own conceptions of who scientists are and what they do.

#### **Information Gathering Activities - *Scientists Are Real People!***

Learning about specific scientists helps to make science personal and, therefore, real. After learning about a particular scientist, a surprised child exclaimed, "Scientists are real people!" We thus had a name for our information gathering activities.

One unanticipated outcome of the interview assignment was the need to actually define “scientist” in broad and varied ways. As scientists, most of us naively assume that people know who we are and what we do. In class, the teachers share their interviews in small groups. Many are surprised to learn that scientists like what they are doing, that many of them became interested in science late in their elementary career or in middle school, and that they recommend hands-on experimenting as the way to teach science. Most assignments are not life-changing, but each semester a few teachers report significant personal events related to the interviewing assignment. One that remains most vivid for me is a young woman who was in tears as she explained her interview. This young woman was pregnant, had been married for approximately six years, and couldn't believe that she had not known what her husband did. She summed up her feeling when she asked, “What have we talked about for the last six years?” Later in the semester she became excited and started shouting, “That's it, that's it, that's what he does” as she pointed to the screen on which played a short videotape on remote sensing research.

Gender discrimination in teaching is a behavior that pre-service teachers either denied they did, or would do, until we found a videotape of teaching on which to base the discussion. Actually watching effective teachers unknowingly discriminate against female students raises the level of awareness on the complexity of teaching to all students. It also provokes discussion on things to watch for and strategies for analyzing their own teaching.

Learning about their own preconceptions and gathering information about scientists are ways teachers can learn about scientists and increase their knowledge about a diverse group of people.

### **Adapting Lessons Activities**

By adapting lessons for specific students, teaching lessons, and critiquing lessons taught, the pre-service teachers expand their repertoire of teaching strategies and student needs. After these activities, they are better prepared to investigate how to teach science to children who have diverse needs, abilities, and backgrounds. The strength of the program is not based on a single activity: it is found in the series of activities that together provide an *emphasis on meeting diverse needs*.

### **Opportunities for Further Action**

The awareness and information gathering activities are working as well as they are because they enable the pre-service teachers to plan for teaching, to articulate what they have

done, and to understand how this knowledge can actually help students learn. However, the immediate application of this information to a real teaching situation with children, instead of their peers, would enhance the learning experience. Teachers would then be analyzing videotapes of their own classroom teaching. A solution might be to have pre-service teachers work with special needs children in a tutoring situation or assist a teacher with the special needs of a child in class before they begin their own student teaching assignment. ■

## References

- [1] *Standards of Learning for Virginia Public Schools*. Board of Education, Commonwealth of Virginia. Richmond, VA, 1995.
- [2] *National Science Education Standards*. National Academy Press, Washington, DC, 1996.
- [3] *Benchmarks for Science Literacy*. American Association for the Advancement of Science: Project 2061, Oxford University Press. New York, 1993.
- [4] "Early Learning Effects on Female Students: Gender Bias in the Classroom," *Dateline NBC*, Hosts Jane Pauley and Stone Phillips, NBC Network, 1993.



**INTERVIEW WITH DONNA STERLING**

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** I was a research scientist, but married someone who traveled throughout the world. As a result, I began teaching early in my career. My travels made for a high level of multicultural awareness from a personal perspective. In the various countries in which we lived, such as Thailand, I was a cultural minority as well as a minority in terms of being a female scientist. I understood the situation and loved the challenge since I thrive on change. These experiences fueled my interest in issues on diversity.

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** Because of my experiences in other countries, my observations of prejudice, and my sincere interest in cultural understanding, I wanted to create a program for science teachers to further their understanding of cultural diversity and gender equity among scientists. In addition, as a teacher, I often meet students who are from other countries. In many cases, I have lived or traveled in their country. This gives us a natural connection. Helping teachers to connect with their students and their students to connect with the science being taught are all part of good teaching.

**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** I was surprised to find that many college graduates did not know what were typical science careers. This came to light when K-8 pre-service teachers had to have a discussion about who were scientists before they could complete an assignment to interview a scientist. In addition, I am flabbergasted at the stereotypes people have about scientists at times. These often come out when I have students draw a scientist or in classroom discussions.

**Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on your program “Diversity Education for Pre-Service Science Teachers?” What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?**

**A:** I've learned that change takes a long time. I am still surprised by how long it takes sometimes. I believe awareness of equity issues is the first step in attaining diversity and gender equity. In many cases it is not easy to raise people's level of awareness. For example, in my classes conversations on gender equity were filled with denial before we began using a videotape of a teacher unknowingly discriminating against girls. People initially refused to believe that they would discriminate, until they saw a good teacher doing some of the things we spoke of in class. They could actually see it on tape. Through viewing videotapes and classroom discussion, a large amount of self-awareness was gained, along with a realization of student-to-student and teacher-to-student relationship dynamics. My greatest reward is visiting with teachers and talking about all the things they're doing now with students as a result of taking the pre-service science methods course.



# **WOMAN, WIFE, MOMMY, AND SCIENTIST: THE IMPACT OF A READERS' THEATRE PLAY ON ELEMENTARY PRE-SERVICE TEACHERS' UNDERSTANDING OF GENDER ISSUES**

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A century ago, few women worked in a science-dominated occupation. Today, females work in all areas of science. Despite an increase in the number of women in the sciences, they *still face difficulties* when it comes to accessing math and science occupations. Gender stereotypes continue to exist. Young ladies still select jobs that are familiar to them, jobs associated with female role models. It was reported by the American Institutes for Research in 1998 that 90% of the women at a job fair flocked to the business aide (i.e., secretarial and administrative assistants) and health care professions that are primarily associated with females [1]. These same professions offer lower salaries, less prestige, and little autonomy, yet women continue to choose them.

Improvements have been seen in math and science course-taking patterns. Since 1990, the difference between the number of girls and boys enrolled in math and science courses has decreased. Even though more girls are now taking physics classes in high school, a lower percentage of girls are majoring in physics in college [1]. Because such discontinuities still exist in gender profiles, it is important to continue to recognize and challenge gender stereotypes as we question patterns of continuing inequity between boys' and girls' career choices.

## **Readers' Theatre**

Readers' theatre is a unique form of presenting human situations in a dramatic format. It is an informal, innovative, and structured method that allows participants to assume and to experience the roles of others. There is no need for scheduling rehearsals or practices, memorizing parts or lines, painting or managing props, or acquiring scenery or costumes; readers' theatre may be performed within the confines of a traditional classroom setting. The key to readers' theatre is utilizing a script that allows a reader, or group of readers, to read passages aloud from the chosen dramatic text, thus capturing the interest of the audience. Student readers themselves become engaged in the drama, play an active part in the implementation, and can be involved in the evaluation of the exercise.

As a dramatic tool, readers' theatre involves students in a variety of learning experiences, tapping them at physical, emotional, verbal, and intellectual levels [2]. Furthermore, readers' theatre attempts to increase students' sensitivity to the difficult emotional situations of others and, therefore, encourage tolerance [3]. At various levels, readers' theatre illustrates a point by creatively setting a mood to teach concepts and having children gather information through group interaction. More importantly, this form of drama can elicit empathy by expressing attitudes and concerns through various characters. The participants in a readers' theatre presentation can examine multiple perspectives by analyzing characters and developing interplay between personal and empathetic feelings [3.5]. Finally, this kind of activity can allow students to verbalize problems, while at the same time maintaining a distance from their own insecurities [4]. Student participants can question, react to, discuss, and reflect on issues that they might otherwise be hesitant to address [3]. In this way, readers' theatre can alleviate fear of embarrassment over certain social or personal conditions by giving the student a "voice," other than his or her own, through which to act out the focus of their own concerns. They can act freely, without any fear of personal cross-examination by peers. In a sense, the student is able to examine the situations created by the dramatic text by using a character's voice, yet still vocalize his or her own internal concerns.

### **A Project Using Readers' Theatre to Address Issues of Sexism in Science**

Readers' theatre was used in our project, "Woman, Wife, Mommy and Scientist: The Impact of a Readers' Theatre Play on Elementary Pre-Service Teachers' Understanding of Gender Issues." The information in the play was the result of a two-year long qualitative research project. A major emphasis of qualitative research involves the development of a highly detailed description of subjects that includes direct quotations capturing personal perspectives and real-world experiences. Also, the researcher's personal experiences and empathetic insights are an important and critical part of qualitative inquiry [6], much the same as the relationship assumed between the readers and the characters in readers' theatre.

The play discussed in this paper is a readers' theatre production in which the characters are actual female scientists who participated in a research study coordinated by the University of Virginia in 1994-96. The script communicates the results of the research through the words of the participants of the study. The readers who read the script, volunteers from a group of elementary pre-service teachers, represented women who revealed how they became established, credible scientists. Just as the women scientists' stories presented a developing paradigm shift in the roles of women in the culture of science, the young teachers-to-be who read the words of the *women scientists* also experienced that shift, and reflected upon their own situation.

The day the script was read, students came to class without any prior notice that they would be performing a play together. At the beginning of class, the instructor asked for volunteers to portray each of the six women. Those who volunteered were given scripts with their parts highlighted, and place cards designating their role to set in front of them. The readers were told to follow along in their scripts, and to try to come in promptly when it was time to read their part. They were also instructed to "read loudly and clearly, and don't hesitate to put feeling or emotion into the part you're reading." The instructor played the part of the researcher while the rest of the students in the class listened. Following the performance, there was a question and answer period in each of the three classes. Just prior to dismissal, students were instructed to fill in the questionnaire as a homework assignment.

Since the readers' theatre presentation was the primary instruction provided on gender issues, it can be concluded that questionnaire and survey results related to this topic reflected the impact of the readers' theatre play. Student groups at three sites, the University of Virginia in Charlottesville, Salisbury State University in Maryland, and St. Norbert College in Wisconsin, read through the script and responded to the questionnaire. The students were all in elementary science methods courses at their institutions. There were 68 students in the three classes and, of the 68, 61 were female.

The University of Virginia pre-service elementary science education class is a component of the approved elementary education program, as are the classes at Salisbury State University and St. Norbert College. Approximately eight of the students at UVA were in the Post Graduate Master's of Teaching (PGMT) elementary education program, a program for persons who already have a bachelor's degree in a subject area. Students at UVA were either fourth-year or PGMT, whereas students at Salisbury State were juniors. Students at St. Norbert were sophomores or juniors. St. Norbert and Salisbury State have four-year programs in elementary education.

## **Results**

In addition to the questionnaire completed after the performance, a survey was administered to the classes early and late in the semester that included items about gender issues and education. Survey data were collected using an adaptation of the Attitudes Toward Computer Technologies (ACT) and Self-Efficacy for Computer Technologies (SCT) instruments developed by Delcourt and Kinzie [7]. Data were collected on attitudes toward educational technologies and science education issues, as well as on perceived self-efficacy with these same categories. Three issues were addressed in the survey that clustered around diversity and inclusion in science

education: gender issues, special needs issues, and multicultural issues. Pre-test results showed pre-service teachers gave the lowest rating in their acceptance of the usefulness of knowledge of gender issues, compared to multicultural and special-needs issues. Gains were seen in the post-test in acceptance of the importance of knowledge on the three topics with the greatest increase in gender issues, with 68% feeling strongly on the pre-test and 87% feeling strongly on the post-test.

**Pre-test to post-test change in agreement about the importance of knowledge of . . . on a day-to-day basis (N = 68-70)**

"Strongly Disagree" responses to the query, "I don't have any use for knowledge of . . . issues on a day-to-day basis."

	Pre-test	Post-test	Change
Gender Issues	68%	87%	+19
Multicultural Issues	83%	88%	+5
Special Needs Issues	85%	91%	+6

The self-efficacy measure (I feel confident with my understanding of . . .) showed a similar low-level of confidence for all three issues on the pre-test. Post-test results showed gains in self-confidence in all three categories.

**Pre-test to post-test change in self-efficacy (N = 64 to 68)**

"Strongly Agree" responses to the query, "I feel confident with my understanding of . . . issues related to elementary science education."

	Pre-test	Post-test	Change
Gender Issues	21%	69%	+48
Multicultural Issues	21%	73%	+52
Special Needs Issues	15%	55%	+40

Students also contributed data on the impact of the readers' theatre play in their answers on the questionnaire administered immediately following the performance. Responses to the questionnaire were coded to protect the identity of the respondents. The questionnaires contained four questions related to the impact of the readers' theatre presentation and also solicited short responses from the students.

Pre-service elementary teachers in the science methods courses at the three institutions reported that the readers' theatre script was much more interesting than reading a research paper, and that it kept their attention. Several members of the classes reported that, because of the readers' theatre format, there was a sense of a real person and not just a person in a textbook. In response to a question about the impact of the information in the readers' theatre script upon their teaching, students said they would teach that science can be compatible with having a family. They also said that, as teachers, they would encourage all students, especially females, to reach their goals and follow their dreams. The pre-service elementary teachers resolved to introduce positive role models, like the scientists in the readers' theatre script, to their female students. At the same time, however, the exercise reminded them that there still are gender biases. As future teachers, the students reported that they would strive to overcome gender bias in their classrooms. A male student in the UVa class stated:

“When I teach, I will make sure that females are given the same opportunity as males to work with hands-on activities.”

“I think that I'll be more aware during group time in encouraging all students to take part in all activities.”

### **Analysis**

The results of this project showed that the readers' theatre approach was effective in informing an audience about the lives of women scientists. It engaged the students of these pre-service elementary science methods classes in an active portrayal of the lives of six women and, in doing so, enabled the students to identify with these women scientists. The survey results showed the potential for readers' theatre productions to effect change in attitudes about issues such as sexism in society. The relatively low percentage of students who felt strongly about the importance of understanding gender issues at the beginning of the semester contrasts greatly with the end-of-semester results. Many students changed their attitude about the day-to-day importance of knowledge about gender issues. Also, prior to the readers' theatre play, responses to the survey questions on the three issues questions—gender, multicultural, and special-needs—show a difference among attitudes toward the three. Many more students considered knowledge of special-needs and multicultural issues to be more important than they considered knowledge of gender issues. Survey results at the end of the semester show that gender issues were considered similarly important to the other issues. The self-efficacy question results show a low level of confidence in understanding all three issues, and there is a large increase in confidence in all three at the close of the semester.



Questionnaire results reflect the aspects of engagement and empathy indicated in literature on the usefulness of readers' theatre. Student responses indicated an increased awareness of the dilemma posed between the demands of traditional female roles and the demands of science careers.

Since the readers' theatre performance was the primary avenue for addressing gender issues, it is reasonable to infer that the performance and subsequent question and answer session contributed to the changes seen in the survey responses, and to the changes reported on the questionnaire. Readers' theatre provides a venue for maintenance of emotional distance so the audience may address a complex array of issues and develop ideas about how they, members of the audience, reconcile their personal feelings with their empathy for the characters.

Changes in stereotypical attitudes and behaviors are not easy. The very benefit of stereotypical behavior is an assurance of social acceptance and belonging, and a relaxation of behavioral oversight of one's self. Sexism is one of the "big three" stereotypes, along with racism and ageism, and is extremely difficult to alter [8]. However, student responses following participation in this readers' theatre show a change in attitude and in confidence in understanding the issue of sexism in the field of science.

To say that the results of this project show that change will be reflected in the classrooms of these pre-service teachers is optimistic, but possible. If larger purposes and directions, such as rebutting sexism in science, are to be infused into the stress of day-to-day tasks of teaching elementary and middle school, then pre-service teachers require exposure to the issues in a manner that is non-threatening, engaging, and creative. In addition, the stories of these particular women show that certain cultural stereotypes that have restricted women—those involving duty, responsibility, and fulfillment as a wife and a mother—can be reconciled with the role of scientist. In many ways, readers' theatre builds a bridge of understanding for issues that may threaten an audience, while at the same time the women's stories create yet another bridge between the traditional roles of women as wives and mothers and the, as yet, untraditional roles of female scientists. ■

## References

- [1] *Gender Gaps: Where Schools Still Fail Our Children*, American Institutes for Research, American Association of University Women Educational Foundation, Washington, DC, 1998.

- [2] R. Coney and S. Kanel, *Opening the World of Literature to Children through Interactive Drama Experiences*, Paper presented at the Annual International Conference and Exhibition of the Association for Childhood Education, Portland, OR, 1997.
- [3] A. Albert, "Drama in the Classroom," *Middle School Journal*, **25**(5), (1994) 20-24.
- [4] D. Gordon, *Playing it Safe: Dramas, Stories and Lessons about AIDS*, LSH Women's Program, 1340 Frankford Ave., Philadelphia, PA 19125, 1992.
- [5] N. Morgan and J. Saxton, *Expression and Meaning: The Two Frames of Dramatic Experiences*, Paper Presented at the Annual Meeting of the American Theatre Association, San Francisco, CA, 1984.
- [6] M.Q. Patton. *Qualitative Evaluation and Research Methods*, Sage Publications, Newbury Park, CA, 1990.
- [7] M.A. Delcourt and M.B. Kinzie. "Computer technologies in teacher education: The measurement of attitudes and self-efficacy." *Journal of Research and Development in Education*. **27**(1) (1993) 35-41.
- [8] D.M. Wegner, and J.A. Bargh. "Control and Automaticity in Social Life." in D.T. Gilbert and S.T. Fiske (eds.). *The Handbook of Social Psychology*. McGraw-Hill, Boston, MA, 1998.

**INTERVIEW WITH JUANITA JO MATKINS**

**Q: What career path did you follow to reach your present position? Is this what you originally aimed for, or were there twists that brought you here?**

**A:** Considering that my ambition in undergrad school was to become a professional actress and director, I would say that there were definitely some twists and turns along my path! I have always been something of a crusader, though, and resolute in my determination to work towards a better world. That is consistent with the choices I made along the way that led me to become an elementary teacher. Once I saw teaching as a vehicle for making a difference in a kid's life, and for helping effect positive change, teaching was the way for me. I went back to school in 1976 and obtained my elementary teaching license along with my Master's degree in elementary education. I taught in Louisa County for almost twenty years, mostly in the elementary grades. While teaching elementary school, I was invited to become the science resource teacher for a new school that was equipped with a science lab. What great fun that was, teaming with classroom teachers and working with all the children at Jouett Elementary School, in Louisa, Virginia! The ability and the eagerness of those children to learn science belied my own elementary school experiences, and I began to question the sexist, racist, and economical/elitist attitudes of my own culture towards children's abilities to learn science. From this, I determined to move beyond K-12 education and work at the college level, training elementary teachers and doing research to make science more accessible to all.

**Q: Have you been involved in similar programs before? Was there a particular moment or stimulus that caused you to begin this project?**

**A:** I'd never written a readers' theatre script before I began this project. Looking back on my theatre experience as a (much) younger woman, though, it was a natural outgrowth of that training and my frustration with the way traditional research seemed to "miss the point" in communicating the heart and soul of these women scientists I had studied. If there was one moment or point when I began, it was probably after the second presentation I did on the women scientists' research, when I realized how frustrating it was to me that the audience seemed distanced from the information provided. I wanted to bring the audience emotionally closer to the realities of women struggling as scientists while finding their place as wives and mothers.

**Q: Have there been any unique or unexpected consequences for you resulting from your project?**

**A:** I was surprised at the very positive reception of presentations of the readers' theatre script at two conferences where the organizations had a reputation for scientific objectivity: the National Association for Research in Science Teaching and the American Meteorological Society. After both readings, women and men came up to me to talk about their personal experiences with the same phenomena revealed in the readers' theatre stories. It became clear to me that there was a universality to these women's stories.

**Q: Are you able to identify the greatest lesson you have learned and the rewards you have gained through working on “Woman, Wife, Mommy, and Scientist?” What is the greatest benefit you see coming to students—and teachers—through their engagement with this project?**

**A:** There is a perception in the culture, reflected in the questions from the audience following the presentation of the script, that sexism no longer exists in our society. Nonetheless, my own students at UVA shared stories of sexist practices in their own families that show that this issue has not gone away. The greatest reward I get from this project is when I see renewed resolve in the eyes of a woman or man as the stories of these six women scientists are examined. I don't suppose that one reading of a script will change entrenched attitudes toward women, but I believe that this script has an emotional impact that lingers. I do hope that those who come to the play with sexist attitudes will be uncomfortable with those same attitudes when they leave.



## RECOMMENDATIONS FROM CONFERENCE PARTICIPANTS

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In order to better understand effective strategies to increase the success of women, minorities, and members of other groups who have been underrepresented in science, mathematics, and technology, the Virginia Mathematics and Science Coalition convened a statewide conference, "Programs That Work," in Chester, Virginia on March 23-24, 2000. Eleven exemplary programs were highlighted at the conference. Over 100 individuals participated, including: leaders of the exemplary programs, K-12 and college faculty and administrators, scientists, corporate representatives, public sector leaders, and members of the Virginia Mathematics and Science Coalition.

The participants developed the following recommendations for the Virginia Mathematics and Science Coalition and for interested Virginia communities.

### I. Teacher Preparation

Well-prepared teachers are a key factor in increasing the numbers of minority members and women in the technological workforce. As is the case nationwide, Virginia is beginning to experience a shortage of teachers. This shortage exists in most regions of the state, at most grade levels, and in most subject matter areas. The need is particularly great in urban and rural school systems, and in the subject areas of mathematics and science.

Virginia must produce more teachers who are well prepared in their subject areas and who possess an understanding of how students learn. Minorities and women can help Virginia meet these critical needs. In turn, these teachers can be particularly effective in recruiting future generations of women and minorities to all technological fields.

**Future teacher recruitment:** Future Teacher Associations are effective recruiting tools and should be organized for students at all grade levels. Enrichment programs, such as those similar to "Programs That Work," should incorporate a component that encourages students to consider teaching as a career. Another population to consider would be college freshmen who have not yet finalized their career plans. Finally, programs that give students the opportunity to become involved with schools are a particularly effective recruitment tool.

**Teacher preparation:** Disciplinary faculty in mathematics, science, and technology must be assigned a meaningful role in the development of and participation in teacher preparation programs. It is crucial that these faculty offer high quality courses that “model” the type of instruction all teachers should provide, including diversity and special needs issues.

**Financial incentives:** In order to attract the best teachers who can provide high quality practicum and student teaching experiences, adequate compensation must be provided. In addition, attention must be paid to the high cost of education; those in teacher preparation programs in such high-need areas as mathematics and science should be considered for “forgivable loans”; i.e., loans which may be forgiven if the teacher fulfills the requirement of teaching a set number of years.

## II. Professional Development and Instruction

School systems and the broader community need to provide teachers with much more complete support through their careers. Teachers teach most effectively if they: are given current classroom facilities and equipment; possess the on-going ability to update their skills and knowledge with the financial blessings of the school system; and, have access to professional development models with proven educational research that can be put into practice.

**Support for Beginning Teachers:** Strong mentoring programs providing support from outstanding veteran teachers are needed in all schools. Experienced teachers who have opted for early retirement are particularly good candidates for mentors. Apprenticeship programs that provide for gradual immersion into the profession have proven to be effective. It is recognized that such programs are very expensive; however in the long run, they are cheaper than placing individuals who have not completed full teacher preparation programs directly into the classroom in an unsupported manner.

**School system support:** Continuing teachers should be provided with good classroom and laboratory facilities equipped with up-to-date technology. Having this technology in place, it is especially important that teachers be allocated adequate planning time for collaboration, and development of interdisciplinary and enriching active-learning strategies.

**Professional development:** All teachers need to be provided with continuing professional development opportunities and incentives for participation, including merit increases, stipends, and extended contracts.

**Development models:** Teachers need professional development models to assist them in implementing documented educational research in areas such as, gender and ethnic equity, content and process instruction, curricula analysis and assessment, and processes through which students learn.

### III. Special Programs

Well prepared teachers working in a school that is committed to providing a quality education for all students is a necessary condition to increasing the success of women, minorities and others. However, this is not sufficient. Students need advocates, mentors, and programs that provide enrichment and encouragement beyond what school can provide. The conference participants were impressed with the effectiveness of special programs, including the “Projects That Work” that were recognized at the Coalition conference, designed particularly for women, minorities, and other individuals who have not traditionally been heavily represented in the sciences and technological areas.

**Partnerships:** Many resources in the community are available and need to be marshaled. Various partners such as museums, government offices, communities, churches, and colleges are making important contributions in this area and their work needs to be recognized.

**Technology:** Programs are particularly needed to help reduce the “digital divide” found in many disadvantaged and minority households. Computer loan/donation programs from corporations are one possibility.

**Resources:** Mechanisms need to be established to enable individual classroom teachers to learn about what is available for students in their classrooms.



#### **IV. Role of the Family**

The role of the family in nurturing student success cannot be underestimated. The important ingredient is the interest, support, and encouragement of the child's family. While family members who have been successful in academic endeavors, particularly in mathematics and science, can serve as strong role models, those with only limited education can also make important contributions to a child's success. For example:

**Learning By Example:** It is important that children see that their parents and other family members care about education. Family members who are in the process of earning a GED diploma or returning to school can make a huge impact by doing their homework while the child is doing his or her homework.

**Home Enrichment:** Parents can create a climate of learning by creating a home learning center, by mounting displays of children's work, by asking the child what he or she is learning at school.

**Contribution of Parents to Schools:** Family members, including those with very little formal education, can make contributions to their schools. Schools can make an important contribution to their student's success by recruiting parents, particularly parents with little formal education, to assist. For example, as a first step, parents could be asked to collect items such as egg crates, lids, paper rolls, buttons, and fabric scraps that can be used in the classroom. Then these parents can be encouraged to come to school and help with individual students, perhaps as reading partners. They can also be recruited to put together science experiments before the class to help the teacher. Parents can provide childcare so that another parent can volunteer in the classroom.

#### **V. Role of the Coalition**

The Virginia Mathematics and Science Coalition has the potential to have a major impact on the success of women and minorities in mathematics, sciences, and technology.

**Partnerships:** The Coalition should develop its capacity to foster partnerships with religious and community groups, and organizations of influence for the purpose of encouraging and supporting mathematics and science education.

**Business Community:** The Coalition should work to actively involve the business community in helping to bridge the digital divide and in articulating the need for well prepared students in mathematics, science, and technology areas.

**Refinement of Standards of Learning:** The Coalition should continuously remind the public that the Virginia Standards of Learning tests, when carefully constructed and refined, can serve to help increase student learning and success. This increase in student success is the only justification for the standards and is the reason that the nature of the questions on the examination are of critical importance.

**Financial Support:** The Coalition should strongly recommend to the General Assembly that financial support for mathematics and science specialties at the elementary and middle school levels are a high priority. In addition, it should advocate the provision of forgivable loans to prospective teachers, particularly to those in areas of high need such as science, mathematics, and technology.

**Recognition:** The Coalition should continue to recognize “Projects That Work” to encourage the individual, personalized, caring approaches that can make the difference in individual lives. ■



# **The Journal of Mathematics and Science:**

COLLABORATIVE EXPLORATIONS

## **PART II: REGULAR JOURNAL FEATURES**



## A SIMPLE ANHARMONIC OSCILLATOR

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### Introduction

The mathematics curricula in the Upper Schools of St. Catherine's and St. Christopher's Schools are coordinated with students from the two schools sharing classes in the eleventh and twelfth grades. For the past several years, the schools have offered courses in which students take advantage of the power of *Mathematica* to attack difficult problems and to pursue projects in mathematics and science which require extensive computation. In this paper, we shall describe a project undertaken and completed by the first author with the aid of *Mathematica*[1]. The work was performed with the guidance and assistance of her mathematics and physics teachers, the second two authors named above. Katherine presented her results at the annual meeting of the Virginia Association of Independent Schools in November 2000. We shall present our work in narrative form and chronological order without assigning credit for particular results to individual authors.

We set out to develop an idealized mechanical model that would execute simple anharmonic motion, to write an equation of motion for the oscillator, and to solve the equation with the aid of *Mathematica*. We also wished to animate the motion and, finally, we added an experimental component to the project. Throughout our paper, we shall draw boxes about *Mathematica* commands, inputs, and outputs to separate them from the rest of our text.

### The Simple Harmonic Oscillator

Let us begin by recalling the simple harmonic oscillator. Suppose that a block of mass  $m$  is attached to two identical massless springs as indicated in Figure 1. All motion of the system is confined to a horizontal, coordinate plane. The springs have Hooke's Law force constant  $k$  and unstretched length  $L \gg 1$ , and the dimensions of the block are negligible when compared with  $L$  and 1 unit. The ends of the springs which are not connected to the block are anchored at the points  $(0, L)$  and  $(0, -L)$ .

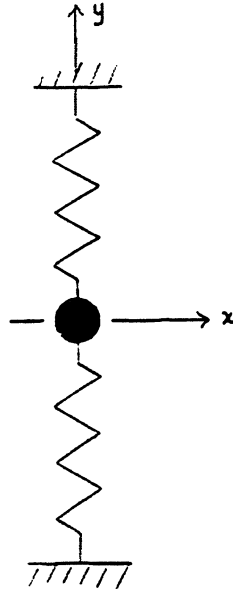


Figure 1. The Simple Harmonic Oscillator

We now suppose that the block is displaced to the point  $(0, 1)$  and then released from rest. The block will execute simple harmonic motion on the  $y$ -axis. Since there are two springs providing restoring forces upon the block proportional to its displacement, the equation of motion for this simple harmonic oscillator is

$$m d^2 y / dt^2 = -2k y.$$

The well known solution to this equation under the initial conditions  $y = 1$  and  $dy/dt = 0$  at  $t = 0$  is  $y = \cos(\sqrt{2k/m} t)$ . The period of the oscillatory solution is  $2\pi\sqrt{2k/m}$ . Later, we shall compare these results with those which we obtain for the simple anharmonic oscillator.

### The Simple Anharmonic Oscillator

A vibrating mass for which the restoring force is directly proportional to the third power of displacement is known as an anharmonic oscillator. To model such an oscillator, we suppose that we have displaced the block to the point  $(1, 0)$  on the  $x$ -axis. If we release the block from

rest, it will vibrate back and forth along the x-axis with an amplitude of magnitude 1 as indicated in Figure 2.

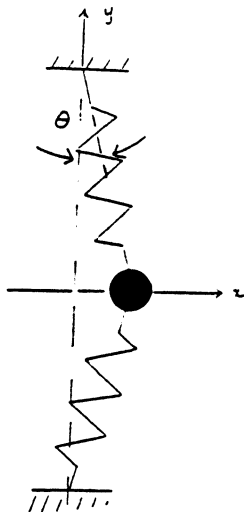


Figure 2. The Simple Anharmonic Oscillator

When the displacement of the block is  $x$ ,  $-1 \leq x \leq 1$ , the stretched lengths of the two springs are  $\sqrt{L^2 + x^2}$ , and the tensions in the spring have magnitude  $k(\sqrt{L^2 + x^2} - L)$ . The x-components of these tensions provide the unbalanced force which accelerates the block back and forth between  $(1, 0)$  and  $(-1, 0)$  on the x-axis. Thus, each spring contributes a restoring force of magnitude  $k(\sqrt{L^2 + x^2} - L)\sin\theta$ . Angle  $\theta$  is shown in Figure 2, and it should be clear that  $\sin\theta = x/\sqrt{L^2 + x^2}$ .

The equation of motion for the transverse vibration of the block along the x-axis is

$$m d^2 x / dt^2 = -2kx(\sqrt{L^2 + x^2} - L) / \sqrt{L^2 + x^2} = -2kx(1 - 1/\sqrt{(x/L)^2 + 1}). \quad (1)$$

Having written an equation of motion far too formidable for our unaided computational power, we now ask *Mathematica* to give us the third order Maclaurin polynomial in  $x$  for the righthand side of the equation.



$$\text{Normal} \left[ \text{Series} \left[ -2k * x \left( 1 - 1/\sqrt{(x-L)^2 + L^2} \right), \{x, 0, 3\} \right] \right] \\ - \frac{kx^3}{L^2}$$

Since we have assumed that  $L \gg 1$ , we feel justified in replacing the restoring force with its third order Maclaurin approximation as output above. Thus we turn our attention to the much simpler equation of motion

$$d^2x/dt^2 = -\left(\frac{k}{mL^2}\right)x^3. \quad (2)$$

We have now obtained our equation of simple anharmonic motion and thus have found a model for simple anharmonic motion.

### The First Integral of the Equation of Motion

We employ a trick well known to those who study mechanics to discover the velocity  $v = dx/dt$  of the oscillating block. The trick which may be termed a “backwards chain rule” is nothing more than the observation that

$$d^2x/dt^2 = dv/dt = (dx/dt)(dv/dx) = v(dv/dx).$$

Equation 2 may now be rewritten as

$$v(dv/dx) = -\left(\frac{k}{mL^2}\right)x^3. \quad (3)$$

We integrate both sides of Equation 3 to obtain another equation which relates velocity and displacement:

$$\frac{v^2}{2} = C - \frac{k}{mL^2} \left(\frac{1}{4}\right)x^4. \quad (4)$$

In this equation,  $C$  denotes the constant of integration. The initial conditions that  $x = 1$  and  $v = dx/dt = 0$  when  $t = 0$  imply that  $C = k/(4mL^2)$ . Thus,

$$v = dx/dt = \pm \sqrt{\frac{k}{2mL^2}} \sqrt{1-x^4}. \quad (5)$$

During the first quarter period of motion,  $0 \leq x \leq 1$  and  $v = dx/dt \leq 0$ . We are able to fix our attention upon the first quarter period by taking the negative sign for the differential equation above.

### The Period of Oscillation

Equation 5 may be rewritten as

$$dt = -\sqrt{\frac{2mL^2}{k}} \frac{dx}{\sqrt{1-x^4}} \quad (6)$$

in the first quarter period. It follows that the period for our simple anharmonic oscillator is given by

$$T = -4\sqrt{\frac{2mL^2}{k}} \int_1^0 \frac{dx}{\sqrt{1-x^4}} = 4\sqrt{\frac{2mL^2}{k}} \int_0^1 \frac{dx}{\sqrt{1-x^4}}. \quad (7)$$

This integration may now be quickly done by *Mathematica* as shown below:

$$4\sqrt{\frac{2mL^2}{k}} * \text{NIntegrate}\left[1/\sqrt{1-x^4}, \{x, 0, 1\}\right]$$

$$7.4163\sqrt{\frac{mL^2}{k}}$$

The period for our oscillator is  $7.4163\sqrt{\frac{mL^2}{k}}$  which may also be written as  $5.24412\sqrt{\frac{2mL^2}{k}}$ .

### The Graph of $x(t)$

Let us define the following function of  $p$ ,  $0 \leq p \leq 1$ , for which  $p$  is the lower limit of a definite integral:

$$F(p) = \sqrt{\frac{2mL^2}{k}} \int_p^1 \frac{dx}{\sqrt{1-x^4}}. \quad (8)$$

The function represents the time elapsed in the first quarter period of oscillation between the release of the block and its reaching the point  $(p, 0)$ . Clearly,  $F(0) = T/4$ .

With *Mathematica* evaluating  $F(p)$  for a very large number of values of  $p$ , we obtained an extensive list of ordered pairs  $(t, x)$  where  $t = F(x)$ . We then employed *Mathematica*'s ListPlot command with the PlotJoined option to obtain the following graph of the first quarter period of the displacement  $x(t)$ .

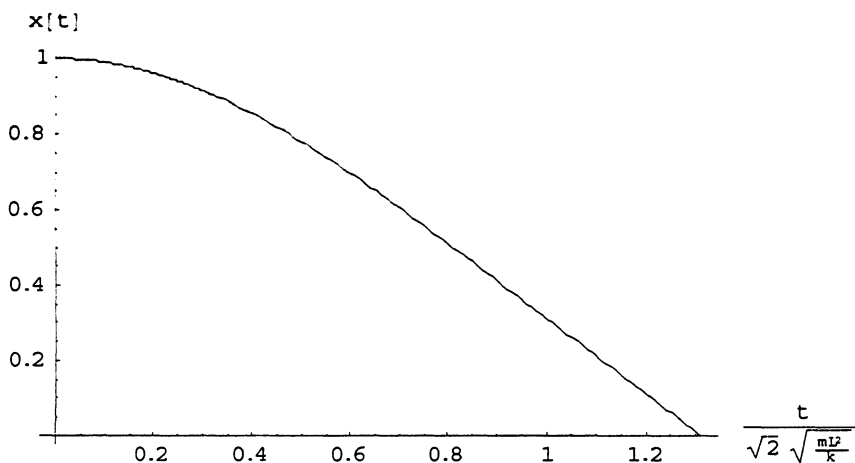


Figure 3. A Graph of Displacement  $x(t)$  for  $0 \leq t \leq T/4$

The graph of  $x(t)$  for a complete period can be pieced together by simply repeating the graph for the first quarter period with suitable translations and reflections. The result is shown in Figure 4. The dashed curve in that graph represents the cosine solution for simple harmonic motion with the same frequency as our simple anharmonic oscillator.

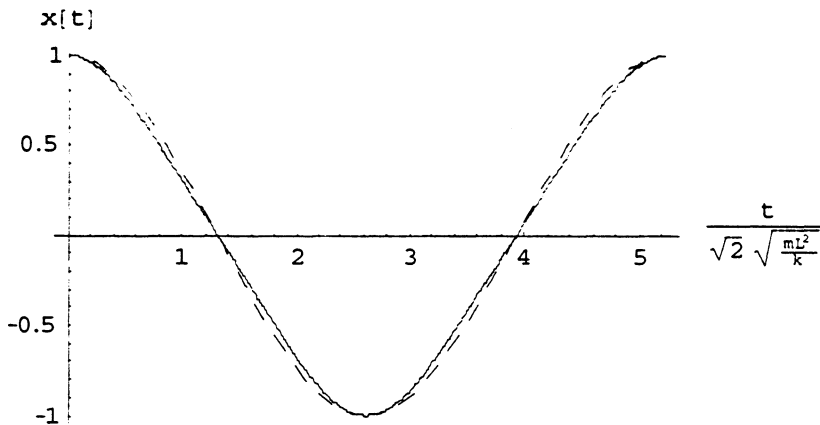


Figure 4. The Graph of  $x(t)$  for One Period with the Cosine Curve Shown for Comparison

### Displacement as a Function of the Independent Variable Time

Thus far, we have accomplished our first three objectives: to create a model of simple anharmonic oscillator, write its equation of motion, and then solve that equation. The function  $t = F(x)$  and the graph of  $x(t) = F^{-1}(t)$  extended to a full period as shown in Figure 4 constitute the solution.

Our fourth objective was to animate the motion of the oscillator by using the powerful graphics commands available in *Mathematica*. Here we encountered a difficulty. In our solution  $t = F(x)$ , displacement plays the role of the independent variable making it relatively easy to obtain ordered pairs  $(t, x)$  for uniform increments in  $x$ , but not in time  $t$ . An animation requires that the variable representing time change at a constant rate. We could have integrated

$F(p)$  using the `If` function to perform the integrations and record values of  $x = p$  when  $t$  reached prescribed values separated by integral multiples of some fixed  $\Delta t$ .

The amount of programming required to implement this procedure did not appeal to us. It has been our experience that easy-to-formulate, but difficult-to-solve problems often have their solutions already built into *Mathematica*. We knew that the closed-form solution to our differential equation of anharmonic motion (Equation (2)) with our initial conditions involves the elliptic function,  $\text{cn}(t)$  the Jacobi cosine-amplitude function. It had never occurred to us that the elliptic functions might be available in *Mathematica*; but we investigated, and discovered to our surprise that we could indeed call for  $\text{cn}(t)$  as `JacobiCN`[ $t, \alpha^2$ ] where  $\alpha$  is the modulus of the function.

We now had the means to animate the motion of the simple anharmonic oscillator. We could have avoided much of the work described thus far had we known before we started that our software would make it so easy to obtain the elliptic functions of the independent variable  $t$ . However, our work was instructive and we would still have needed to integrate for the period of the motion.

### The Elliptic Functions

Although long known, the elliptic functions have fallen out of sight in recent years and are rarely studied today[2]. The complex plane is their natural domain; but for our purposes, their domain may be restricted to the set of real numbers. The restricted functions are periodic and differentiable. Unlike the trigonometric functions which they do resemble, the elliptic functions have periods which depend upon their amplitudes. We note that, in our project, we have simplified matters by assuming  $x(t)$  to have unit amplitude. The three elliptic functions with which we are concerned are the sine-amplitude, cosine-amplitude, and difference-amplitude functions which we denote by  $sn\ u$ ,  $cn\ u$ , and  $dn\ u$ , respectively.

These three functions may be defined by the relationships

$$sn^2 u + cn^2 u = 1 \tag{9}$$

$$dn^2 u + \alpha^2 sn^2 u = 1 \tag{10}$$

$$\frac{d}{du}(snu) = (cnu)(dnu) \quad \text{and} \tag{11}$$

$$sn(0) = 0, cn(0) = dn(0) = 1. \tag{12}$$

As previously noted, the constant  $\alpha$  is the modulus of the elliptic functions. Functions with different values of  $\alpha$  are different functions. Just as the properties of the trigonometric functions may be deduced from the initial statements  $\sin^2 \theta + \cos^2 \theta = 1$ ,  $\frac{d}{d\theta}(\sin \theta) = \cos \theta$ ,  $\sin(0) = 0$ , and  $\cos(0) = 1$ , the properties of the three elliptic functions may be developed from Equations 9 through 12. For example, implicit differentiation of Equation 9 yields  $2snu \frac{d}{du}(snu) + 2cnu \frac{d}{du}(cnu) = 0$ . By Equation 11,  $(snu)(cnu)(dnu) + (cnu) \frac{d}{du}(cnu) = 0$ . It follows that

$$\frac{d}{du}(cnu) = -(snu)(dnu). \quad (13)$$

In like manner, we may derive that

$$\frac{d}{du}(dnu) = -\alpha^2(snu)(cnu). \quad (14)$$

## The Closed-Form Solution of the Equation of Motion

We return to Equation 2. The animation of simple anharmonic motion will require that we assign a numerical value to the coefficient of  $x^3$ . Since the choice is ours to make, we take “the easy way out” and let  $\frac{k}{mL^2} = 1$ . The simplified equation of motion is

$$d^2x/dt^2 = -x^3. \quad (15)$$

Let us assume that  $x(t) = cn(t)$  satisfies Equation 15. The calculations following upon that assumption will force us to a proper choice for modulus  $\alpha$ . Substituting  $cn(t)$  for  $x$  in Equation 15 and using the properties given by Equations 9 through 14 lead to the following conclusions:

$$\begin{aligned} \frac{d^2}{dt^2}(cnt) &= -\frac{d}{dt}(snt \, dnt) = -(cnt \, dn^2 t - \alpha^2 cnt \, sn^2 t) \\ &= cnt(\alpha^2 sn^2 t - dn^2 t) = cnt(\alpha^2 sn^2 t - 1 + \alpha^2 sn^2 t) \\ &= cnt(2\alpha^2 sn^2 t - 1) = cnt(2\alpha^2 - 2\alpha^2 cn^2 t - 1). \end{aligned}$$

We see that  $\frac{d^2}{dt^2}(cnt) = -cn^3 t$  if and only if  $\alpha^2 = 1/2$ . If we let  $\alpha = 1/\sqrt{2}$ , we have  $x(t) = cn \, t$  as the desired solution of Equation 2. Note that the *Mathematica* input of the Jacobi elliptic functions requires the entry of  $\alpha^2$  rather than  $\alpha$ .

Since we have let  $\frac{k}{mL^2} = 1$ , the period of  $cn(t)$  must be 7.4163. In Figure 5, we display the graph of  $x(t) = cn(t)$  for one period. We again show as a dashed curve the graph of the cosine with the same period. We are happy to note that Figures 4 and 5 appear to be identical.

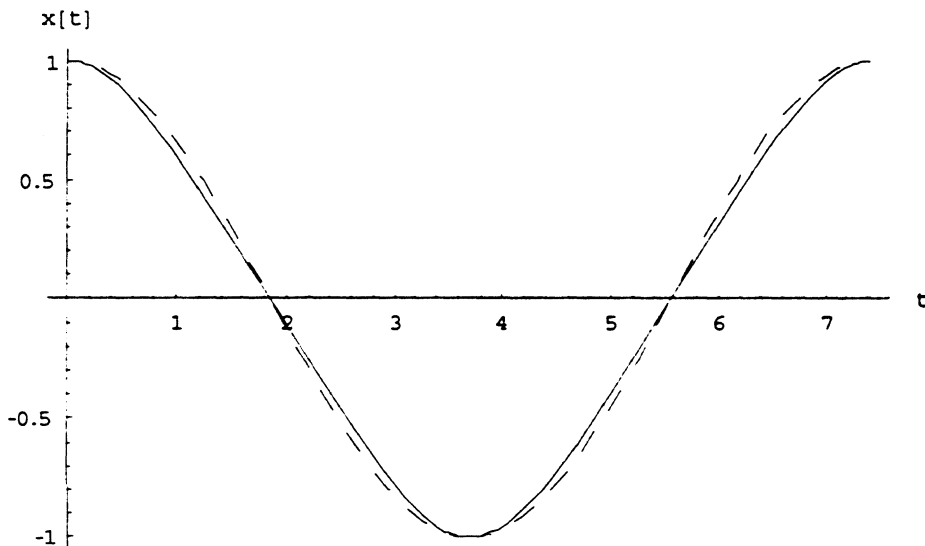


Figure 5. The Graph of  $x(t) = cn(t)$

### The Animation of the Simple Anharmonic Motion

The procedure for animating a motion with *Mathematica* is to create a sequence of  $n$  still images of the changing system. The images must depict the system at times  $t_1, t_1 + \Delta t, t_1 + 2\Delta t, \dots, t_1 + (n-1)\Delta t$  for a fixed value of  $\Delta t$ . Upon command, *Mathematica* will show the images in rapid succession, thereby creating the sensation of viewing the motion. Now that we have  $x(t) = cn(t)$  with independent variable  $t$ , the animation becomes easy to achieve.

The following program created 21 images uniformly separated in time over one period of oscillation. Note that, in the first step below, the constant  $a$  is assigned its value so that  $4\sqrt{2}a = 7.4163$  which corresponds to one period.

```
a = 1.31103
anharpts =
  Table[{4*sqrt[2] a * n/20, JacobiCN[4*sqrt[2] a * n/20, 1/2]}, {n, 0, 20}];

set1[n_] := {{0, 3}, {anharpts[[n, 2]], 0}, {0, -3}}

Do[plot1 = ListPlot[set1[n], PlotRange -> {{-1.5, 1.5}, {-3, 3}},
  PlotJoined -> True, PlotStyle -> Dashing[{0.02}],
  AspectRatio -> Automatic, Ticks -> False,
  DisplayFunction -> Identity];
plot2 = Graphics[{PointSize[0.1], Point[{anharpts[[n, 2]], 0}]}],
  AspectRatio -> Automatic, Axes -> True,
  PlotRange -> {{-1.5, 1.5}, {-3, 3}}]; Show[plot2, plot1], {n, 1, 21}]
```

In the next figure, one frame from the sequence of images is shown. The springs are represented by the dashed line segments.



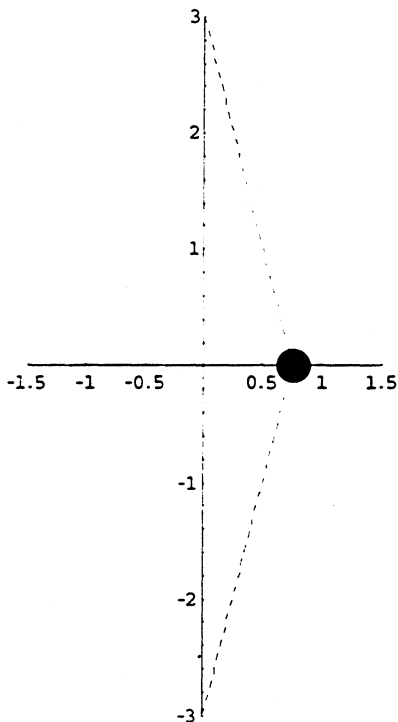


Figure 6. One Frame from the Animating Sequence

### An Experiment

In our advanced physics laboratory, we constructed an oscillator from two springs and a light mass (0.004 kg.) to approximate the ideal oscillator depicted in Figure 1. However, the springs and mass were aligned vertically. The undistorted length of each of the springs was 3 cm. However, the springs were stretched by about 50% of their undistorted length when they were attached to the mass in its equilibrium position. This was done so that the springs would operate in their optimum linear range.

Any additional distortion in the springs produced by the weight of the mass was assumed to be negligible. In any event, no additional stretching of the upper spring and compression of the lower were observed. The stretched length of the springs was large with respect to the dimensions of the mass. The mass (to which we had taped a small section cut from a stiff index card) was pulled aside to a horizontal displacement of approximately 1 cm. and then released from rest.

The motion of the spring-mass system took place in a vertical plane with the mass vibrating on a horizontal line. The length of the springs was always much greater than the horizontal displacement of the mass. We employed a VERNIER™ Ultrasonic Motion Detector and interfaced it with the computer via a U L I in order to record the position of the vibrating mass at fifty equally spaced instants of time per second. The section of index card served to reflect the ultrasonic waves produced by the device. The software program which we used to treat the data was MacMotion (version 4). The next figure displays the displacement of the mass for two consecutive periods chosen well after the motion had settled into a steady pattern. We make no claims that our experimental work was closely controlled or quantitative. It seems to us that the most meaningful use to make of the data would be statistical in nature.

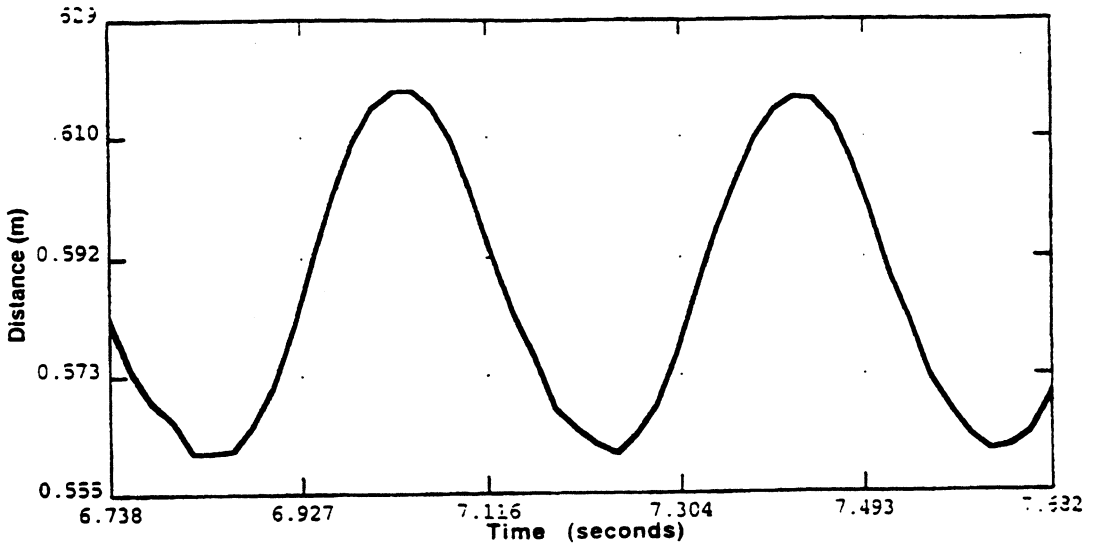


Figure 7. Displacement (Distance) as a Function of Time for the Real Oscillator

In Figure 8, we display nine points  $(x, t)$  within a single period with respect to the dashed cosine graph for the simple harmonic motion of the same period, phase, and amplitude as those of the real motion. The points marked with the symbol “#” are those which we judge to depart from the cosine graph in the manner predicted by Figure 4, in the case that our real oscillator was actually a simple anharmonic oscillator. It had occurred to us that we might look at a large number of such periods and accumulate a count of points “better explained” by an anharmonic model than by the harmonic model of oscillation. We then might do a bit of statistics by developing a nonparametric sign test of the null hypothesis that the data were explained by the harmonic model. We would hope to reject that hypothesis. We decided not to pursue these

ideas, but would be happy to share the data with the joint Advanced Placement Statistics class in our two schools.

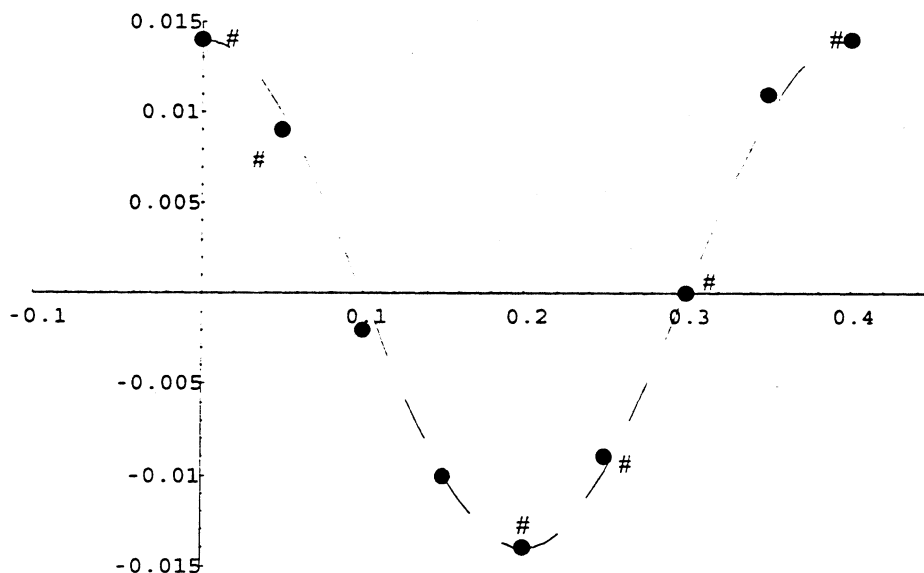


Figure 8. Nine Points  $(x, t)$  from One Period

## Conclusions

All three authors, regardless of the levels of their mathematical and technological sophistication, benefited from participation in this work. Each is able to point out new ideas and combinations of ideas with which he or she had to grapple in order to bring the project to its conclusion. We believe that others teaching and studying in secondary schools at the Advanced Placement Level can with profit and success attempt interdisciplinary projects of the sort which we have described. ■

## References

- [1] B. F. Torrence and E. A. Torrence, *The Student's Introduction to Mathematica*, Cambridge Press, New York, 1999.
- [2] A. C. Dixon, *The Elementary Properties of the Elliptic Functions*, MacMillan and Company, 1894.

## USE OF THE WORLD WIDE WEB IN MATHEMATICS INSTRUCTION

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Many mathematics instructors may find they can use the World Wide Web to distribute information and facilitate discussion and interaction in their classrooms, while actually reducing their administrative workload. Here is a discussion of some of the benefits (including better student understanding!) which an instructor might enjoy from taking the plunge.

There is a lot of discussion in the literature about the ability of new technology to improve the teaching of mathematics, primarily by facilitating better and more exciting presentations by the instructor and better participation by the student in the learning and doing of mathematics. There seems to be little attention paid to the question of how the use of technology, and the World Wide Web in particular, can enable a reduction of the instructor's administrative burdens and improve the real core of the teaching experience—the direct interaction between student and teacher.

In most colleges and in many high schools, access to the World Wide Web is nearly universal. If course documents are already produced on a computer (or easily could be), then significant benefits can accrue by using the web in mathematics courses – including a lightened administrative load, the ability to reach students more individually and efficiently, and more involvement and success for the students.

Future teachers are likely to be among those responding most enthusiastically, since they will be aware of the rapid spread of technology throughout all levels of education. They will expect to be required to use technological resources when they themselves are teaching, and they will welcome the opportunity to become familiar with the web and its various uses.

Using the web is neither necessary nor sufficient for a contemporary college or high school math course. A perceived need to be involved with the newest and hottest thing is not motivation enough. An instructor should be able to see clear and obvious benefits for his or her classes and teaching style.

The web has been used for a number of years in both college and high school math classes, with varying degrees of sophistication and with differing objectives for the role of the web, depending on the teaching style of the instructor and the capabilities and resources of the students. It is not difficult to acquire the minimal specific knowledge required to post documents to the web, and there are many different approaches to mitigate the difficulty of inputting math symbols into a computer. A good first step is to take a minimalist approach. Whatever the structure of the class and teaching method, the instructor can simply replace, whenever possible, documents printed and distributed on paper with the same documents made available on the web.

With that change only, and despite the difficulty of writing mathematics in text editors and word processors, an instructor can use the internet to increase his or her efficiency and improve students' understanding. At lower levels of math, the effectiveness of homework exercises which drill basic computational skills can be improved. In upper level courses, students can receive better coaching on the writing, logic, and organizational skills necessary for writing good proofs. Savings in the time required to perform basic administrative tasks augment this improvement by freeing up time to teach.

Ten reasons to use the web in math classes include:

1. The instructor is probably already producing the basic documents needed for the web.

Nearly any document created on a computer can now be saved to HTML format for posting on the web, retaining formatting, graphics, and so forth. The program MathType—which facilitates the creation of formulas and equations by pointing and clicking—is one convenient way to upgrade the mathematical symbol set built into Word and similar programs, and ease the problem of document creation. A syllabus becomes a home page for the course, with links, to homework assignments and solutions, problem discussion, test results, grades, and other interesting web sites that may interest students.

There is, of course, no shortage of commercially available software to help do all of this in a more professional and automated manner, and there are web sites which will “host” (for free) a home page for an instructor, without requiring any additional software [1]. Taking advantage of such services may improve the look and smoothness of web pages. However, it may require more effort than the instructor is currently expending, since

existing documents often cannot be used, and new ones must be custom made. However, for large courses, with many instructors or teaching assistants, it may be that what would be a large amount of work for a single section, can efficiently be spread over many sections. At any rate, an instructor certainly ought to examine the possibilities of such sites, including those often offered by publishers.

## 2. Paper work tasks will consume less time.

Posting the syllabus on the web makes it the home page for the course. Links are easy to add to homework assignments, any take-home tests, and the solutions to homework assignments, tests, and exams. The same computer programs—especially Microsoft Word—and hardware (a scanner is useful) which created documents to be printed will create the documents to post on the web. So while creation of the documents is identical to the pre-web days, there is no longer the distribution of hard copies, which saves the time of making copies, distributing them, and replacing them when students lose them. When the need arises to update one of the documents, it is particularly easy to do so and then e-mail an announcement to the entire class with one click. Since a student can access e-mail and the web totally at the student's convenience, there is no longer any reason not to be up-to-date on class requirements.

The more documents an instructor can place on the web, the more time will be saved from the administrative tasks of copying and distributing them. On the other hand, posting and maintaining a web site will be non-trivial, also. However, there will be a net gain in time that can then be used for teaching instead of paperwork.

## 3. Web pages do not need to be flashy to be useful and effective.

Instructors should not waste time trying to create exciting web-based material. Even the burden of making a web-available copy of lectures would increase the workload significantly, overwhelming the benefits cited above. There is plenty of interactive material out there (often from textbook publishers), with more arriving daily. As an instructor finds such material which can be helpful to students, it is easy to add links from the class home page to that material. But, nothing should be done to encourage students to believe they needn't come to class. Few of us would have become teachers if we believed direct, in-person contact with our students was of no value.

#### 4. Students will appreciate the additional access to course material.

The fact is well promoted that students have far more diverse backgrounds and current lifestyles than was the case thirty years ago. More students are working, more students are married with family obligations, and more students are commuting greater distances. Since it will be a requirement that students have computers, students will see only an upside to the use of the web.

It is amazing how often a student will send e-mail to apologize for missing a class, and to find out if there are any additional or changed material or assignments. So, students are able to access information when it is convenient for them. They will also be able to work from more convenient locations. It is not at all unusual today to have several students commuting fifty miles or more. Such students particularly appreciate the ability to submit work without having to come to school. The use of the web thus allows the additional flexibility needed by the changed circumstances of many students, without requiring lower expectations and standards for the quality and amount of work the students must perform.

#### 5. Instructors will have another effective avenue of communication with students.

Because of their more complicated schedules, students often find it hard to take advantage of office hours. The expectation that work will be submitted via e-mail, and conversation and discussion encouraged, enables a student to engage in discussions with teachers and fellow students that might not otherwise occur. For instance, it is not hard to employ a system by which students can post comments and questions to a web page. In addition, students in lower level classes, who may be there simply to satisfy the requirements of their major, often feel they are not “math people,” and seem reluctant to reveal their difficulties in face-to-face meetings with their teachers. Some of this reluctance is sometimes reduced when questions can be sent via e-mail (so they can be carefully thought through) and responses can also be read in private (eliminating, perhaps, embarrassment at an “obvious” answer).

The experiences of a number of instructors suggest that this greater discussion occurs both with small sections of ten or fewer students, as well as in larger, lower level courses with section sizes of thirty to forty. This would probably be even more true in the larger classes of several hundred students which occur in some schools, since students are likely to feel even more removed from direct interaction with their instructors.

In fact, in one case, an *Introduction to Analysis* section with six or eight good students was taught with heavy reliance on the web and e-mail for communication between students and instructor. The course was taught during the second semester by an instructor who did not use the web for the course, and who was not even particularly comfortable using e-mail for mathematical discussions. Nonetheless, he encouraged the students to continue e-mailing him with questions. Even though he seldom responded to the e-mail, he found it helped him prepare better for class, since he had a better inkling of the areas of confusion for his students.

#### 6. The difficulties of writing mathematics on a computer can be reduced.

The difficulties of writing mathematics on a computer has been reduced, but probably not completely overcome. It is not yet feasible to require students to use any particular word processor, let alone augment it with a program like MathType. One approach is to develop a Convention on Denotations for each course, to enable students to write mathematics in a text file (the simplest e-mail files). Of course, students who have the higher-powered programs should be encouraged to use their features. Here's an excerpt from such denotation conventions, which typically develop and change over the life of the course, for an *Introduction to Abstract Algebra*. It is rare to encounter a mathematical expression for which a satisfactory "text-only" substitute cannot be found.



**Fractions**

For simple fractions:

$$\frac{1}{2} = 1 / 2$$

$$\frac{x}{x^2 - 1} = x / (x^2 - 1)$$

For more complex expressions:

$$\frac{x+3}{x^2+3} = \text{frac}(x+3, x^2+3)$$

**Functions**

→: Use ->

Write f(g) for  $f \circ g$

**Greek alphabet**

Write alpha for  $\alpha$

Write beta for  $\beta$

Write gamma for  $\gamma$

Write phi for  $\varphi$

**Infinity**

Use infinity for  $\infty$

**Matrices, Determinants, and Tables**

Write  $\begin{pmatrix} a & b & c \\ d & e & f \\ g & h & i \end{pmatrix}$  as

matrix ( a b c

d e f

g h i )

7. At the lower levels, more drill can be encouraged.

In our lower level classes, such as precalculus and calculus, we normally have thirty to forty students and no administrative help for correcting homework and tests. As a consequence, most students are assigned very little, if any, homework that is corrected and returned. Most of the student homework exercises require calculating an answer, not writing a theoretical proof; and, most of our grading does not give partial credit for an answer that is "close," or that used the right method, but did the calculations incorrectly.

Anecdotal evidence supports the belief that the average grade and, of course, understanding, of a lower level class increases directly with the total amount of corrected homework the typical student submits. As use of the web increases, allowing more corrected drill by the students, it is reasonable to expect an increase in the percentage of B's and C's in a class. On the other hand, it is probably rare that homework of this sort would make a significant difference in the number of A's in a class. Depending upon the size and level of the class, several different homework options/approaches are available.

In order to create a reasonable work load for the instructor, minimize the difficulties for students of writing math on a computer, and yet not deprive the students of consistent feedback on the quality of their work, one can choose to simply require submission of the answers to the homework assignment. However, with no supporting work shown, one also sacrifices the ability to comment on the details of the students' efforts.

Multiple choice exercises make the work particularly easy for the student to submit and for the instructor to correct, but multiple choice exercises allow a student to work towards an answer, and guides the student's thinking in too limited a manner. Another approach is to require that the student find the answer, rather than simply choosing one. This approach requires greater reliance on a Convention on Denotations, and requires greater effort and time for correction. In addition, the instructor should write out on a computer all the answers, to assure that each answer can easily be written using the class Convention on Denotations.

A third possibility is now being offered by some web sites (such as that developed by Brooks/Cole, the textbook publisher) which allows the entry (and automatic correction)

of free form answers according to “calculator syntax.” When a phrase such as “ $x^2$ ” is entered for an answer, the phrase “ $x^2$ ” appears on the computer screen, so the student has a chance to review and correct his work before submitting it. None of these approaches is perfect, but each offers significant advantages, particularly compared to the approach of leaving all homework exercises to the students’ discretion.

Textbook publishers and others have programs which allow automatic generation of groups of exercises (from an exercise “bank”) satisfying certain criteria, and sometimes automatic grading of those exercises. While it is possible that the use of such programs would actually take more work than simply continuing present methods, each instructor should make an individual judgment. That judgment would depend on whether a quiz is taken by a single section of thirty students or, for instance, 450 students in fifteen sections.

8. At the upper levels, student logical and writing skills can be improved.

In our upper level courses, such as *Introduction to Abstract Algebra* or *Introduction to Topology*, writing proofs is heavily emphasized. So the advantages to the student of writing up homework on a computer (with text editing abilities) are significant. Because rewriting is so easy on the computer, in some small classes of ten or fewer students I establish a deadline for draft submissions, which encourages students to begin their work early and to seek help when they encounter problems. For instance, here’s how one student’s ideas evolved as I commented on her efforts to express the concept that one set was the Cartesian product of two others.

Her first solution was:

$$iii) x = y \times z \text{ iff } \forall (a,b) ( (a,b) \in x \leftrightarrow a \in y \wedge b \in z )$$

I noted to her:

This is a good beginning idea, but is it possible that some set  $w$  could be an element of  $x$  if  $w$  is not itself an ordered pair?

She next came up with:

$$\text{iii) } x = y \cdot x z \text{ iff } \forall z \exists (a,b) (z \in x \leftrightarrow z = (a, b) \mid (a \in y \wedge b \in z) )$$

My comment to her was:

Ok – here, the use of the vertical line isn't right, and you seem to have used the variable  $z$  for two different purposes. Additionally, the statement would be much clearer if you moved the existential quantifier inside the major set of parenthesis. I think you are trying to say something like, "iff for all  $z$  ( $z$  is in  $x$  iff there is some. . . )"

And I don't think you really want to posit the existence of an ordered pair, rather than the two elements ordered in the pair, since those are the ones you subsequently go on to describe further.

Her final response was:

$$\forall w (w \in x \leftrightarrow (\exists a \exists b) (w = (a, b) \wedge a \in y \wedge b \in z) )$$

Furthermore, in some cases the text editing capabilities of the computer can aid the student in writing better proofs. In a class such as *Introduction to Set Theory*, using these word processing capabilities might help students gain more confidence about how to start or continue a proof because it is so easy to reuse an existing proof! For instance, here's how one student responded to the challenge of deriving a proof of one of DeMorgan's Laws from a proof of the other, by changing "intersection" to "union" and vice versa, and by substituting "and" for "either .. or."

To see that  $\overline{A \cup B} = \overline{A} \cap \overline{B}$ , just note that

$$\overline{x \in A \cup B} \text{ iff } x \notin A \cup B \text{ iff it is not the case that (either } x \in A \text{ or } x \in B)$$

$$\text{iff } x \notin A \text{ and } x \notin B \text{ iff } x \in \overline{A} \text{ and } x \in \overline{B} \text{ iff } x \in \overline{A} \cap \overline{B}$$

To see that  $\overline{A \cap B} = \overline{A} \cup \overline{B}$ , just note that

$$\overline{x \in A \cap B} \text{ iff } x \notin A \cap B \text{ iff it is not the case that (} x \text{ is in } A \text{ and } x \text{ is in } B)$$

$$\text{iff either } x \notin A \text{ or } x \notin B \text{ iff } x \in \overline{A} \text{ or } x \in \overline{B} \text{ iff } x \in \overline{A} \cup \overline{B}$$

Students also get a better sense of what it is to do mathematics, since when they engage in some back and forth discussion with the instructor or other students, they begin intuitively to understand that a proof often does not emerge full-blown in an instant, but may consist of iterations of some good guesses and insights leading to roadblocks, leading again to some more guessing and insights. And, the easy ability to share different proofs of the same exercise on the web can often stimulate students to a better appreciation that there is more than one approach. It is particularly fun to be able to e-mail a student to say that she submitted a proof better than the one I had posted.

## 9. Correcting homework and tests by e-mail will be more effective and efficient.

When homework is sent by e-mail, it tends to be on time, allowing the instructor to correct it when and where he or she wants. And it is legible! There are no words struck out, no ugly erasure marks, no arrows pointing the instructor to answers scribbled in corners or on the back of a page. This can be particularly valuable in the lower level courses, where a student's lack of confidence and interest in the subject may be subconsciously (or consciously!) affecting the quality of the student's work. The job of correcting the submissions thus goes more quickly and pleasantly, allowing the assignment of more work, or the correction of a greater percentage of the exercises assigned.

As remarked earlier, because lower level courses are frequently so large and the prospect of correcting homework so daunting, instructors often rely on the fact that a college student should be responsible for understanding how to work correctly all assigned exercises, as well as for follow-up with questions to the teacher or to other students until

the understanding is complete. But the fact is that many of the lower level students need to learn the skills of studying and self-discipline as much as they need the content of the course. At the lower level, students are seldom skilled or enthusiastic about math, else they would already have taken the courses in high school. Most enormously underestimate the benefits of practice and drill at this level. In particular, if mathematics is the study of pattern, then skill at mathematics is closely related to the ability to recognize patterns. It is, of course, impossible to have a chance of discovering those patterns if not enough work is done, and not enough examples are seen. So a way is needed to give these students a chance to learn the good studying habits that are so essential, but without allowing the burden of correcting homework to take all the joy out of teaching. Submission of simple answers by e-mail seems one good approach to this conflict.

Homework submitted by e-mail allows both the student and the teacher to have copies of the work, and it allows a "marking up" of the work which doesn't destroy the original. And the ease of writing and editing clearly on the computer may enable the instructor to make more extensive comments than might be the case with handwritten student submissions and handwritten corrections.

At the upper level, in particular, where the writing and logical skills needed for proofs (and for life) are stressed, the fact that the work is submitted in a form which allows the instructor to copy parts of it easily is a terrific benefit. What the student has written can be compared to what the instructor would have written; pointing out ways to eliminate ambiguity, to be more rigorous, to be more succinct, and so forth. And, because students frequently have similar difficulties, it is easy to recycle comments originally meant for one student to other students.

All of this greater ease at making comments, suggestions, and corrections can help improve teacher/student relations in ways that somewhat compensate for the students' busier lives and their consequent inability to see the teacher face to face as often as in the "good old days." For instance, a student whom I never saw outside of the classroom had asked me a question in class about ordinals; subsequently, she found it was explained in a homework exercise which developed the idea of the form and uniqueness of the  $n^{\text{th}}$  ordinal. Her submission was:

10. 1st member:  $\emptyset$ , since  $X_{x_0} = \{x \in X \mid x < x_0\}$  and  $x_0$  is the minimal element.

2nd member:  $\{\emptyset\}$ .

The  $n$ th member is given by  $\{x_{n-1}, x_{n-2}, \dots, \emptyset\}$ .

This implies that there is only one  $n$ th ordinal, uniquely determined by the  $(n-1)$ th ordinal.

Ah ... should have done the homework before I asked that question in class.

My response was:

10) is good, too. And while the more homework you do the earlier, the more you get out of class:

You can't always be so far ahead that the text holds no surprises!

Furthermore, the web enables the instructor to encourage students to learn from each other. Good student proofs can be posted with (or instead of) the instructor's solutions, and one student's solutions can be easily quoted to another student. In some upper level courses, a spirited culture of both competition and cooperation has been established; students compete to be the first to post correct answers to certain challenging problems, and cooperate in solving problems by posting suggestions, proposed solutions, and corrections in a "thread" relating to a particular topic.

10. More time for teaching.

I would be interested in your experiences relative to and expanding upon my ten reasons, and I welcome your e-mail. ■

## Reference

[1] VQuad com, Internet: <http://www.vquad.com>

# OVERHEAD PROJECTOR DEMONSTRATIONS USING HOUSEHOLD MATERIALS

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## Introduction

Demonstrations performed on an overhead projector (OHP) can easily be seen by everyone in a large classroom. The ones described here require simple equipment (Table 1) and small amounts of household chemicals (Table 2), making them not only inexpensive, but virtually free of problems with safety and waste disposal. Demonstrations on topics such as the properties of light, behavior of liquids, and the nature of acids and bases were chosen because of their usefulness in discussions of biology or physics as well as chemistry.

## Properties of Light

The interaction of light with a substance can provide qualitative and quantitative information about the substance. The amount of light absorbed is used in analytical chemistry to find the concentration of an absorbing species. The pattern of light absorption gives information about the structure of the absorbing species. Scattered light can be used to distinguish solutions from colloidal suspensions. Rotation of polarized light identifies compounds that exhibit optical isomerism, of particular importance in biochemistry where reactions occur for only one member of a pair of optical isomers. The relationship of color to absorption of light is studied by converting the OHP into a spectrometer. All of these phenomena can be investigated with very simple equipment.

### *Absorption of Light*

Absorbance ( $A$ ), the amount of light absorbed by a species, depends on concentration ( $c$ ) and path length ( $b$ ), according to the Beer-Lambert Law,  $A = \epsilon bc$ . The extinction coefficient ( $\epsilon$ )

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is a constant that depends upon the absorbing species. To observe the effect of path length, identical concentrations of food dyes (1 drop per 4 mL water) are poured into three different beakers using heights of 0.5, 1.0 and 1.5 cm. The colors appear more intense to the eye as the path length increases [1].

To see the effect of concentration, the path length is kept the same while using several different dilutions. The more concentrated the solution, the more intense the color. Since absorbance depends on concentration, it can be used to make quantitative determinations of the amount of absorbing species present in the solution.

### *Polarized Light*

Polarizers absorb all but a single plane of light. Polarizing lenses in sunglasses are set to cut out horizontally polarized light because the glare-producing light reflected from road or water surfaces is polarized in the horizontal direction. Squares of polarizing plastic (Table 1) can be crossed to demonstrate that no light is transmitted, actually very little light since the plastic is not perfect polarizing material.

Chemical compounds that are optically active, like sucrose or table sugar, can be shown to rotate polarized light. When sucrose solution (45g/30 mL) is placed in a 50-mL beaker, light can be seen through crossed polarizers [2-4]. Since different wavelengths rotate to different extents, colors of the rainbow appear as the top piece of polarizing film is rotated.

### *Light Scattering*

A colloidal suspension consists of dispersed particles that are suspended and are too small to settle out. The scattering of light by the particles can be used to distinguish a colloidal suspension, such as milk, from a true solution. This phenomenon, known as the Tyndall Effect, can be viewed on the OHP [5]. The stage is covered using cardboard with a 2-cm hole. Any size beaker containing water to a height between 1 and 2 cm is placed over the hole. The typical yellow color of the overhead bulb is seen. When about five drops of milk is added to the water (stir to mix), the color changes from yellow to red as colloidal particles form and blue light scatters first.

This is the same phenomenon responsible for the color of sunset. Toward evening when sunlight travels a large distance through the atmosphere to reach a point over an observer, much

of the blue light is removed by scattering. When the sunlight, with blue removed, is incident on a cloud the light reflected has a yellow or red hue.

### *Spectroscopy on the OHP*

The OHP is turned into a visible spectrometer [6-8] by putting a 7-cm square of diffraction grating over its lens to separate the light from the projector bulb into colors of the visible spectrum. Project Star plastic diffraction grating (Table 2) is chosen because most of the light appears in the first order. The OHP stage is covered with an opaque housing that has two rectangular openings (1.5 x 3 cm) to provide both a reference and sample beam. The grating is turned so that the two visible spectra appear vertically (red at the top and violet at the bottom). Only partial darkening of the room should be needed.

The color of a transparent film or a solution is compared with its absorption spectrum, which appears as dark bands that remove segments of the visible light. For instance, magenta viewed through the sample slit absorbs green and transmits red and violet. A set of 100 different colored plastic filters, made by sealing dye between two microscopically thin layers of clear film, can be purchased (Table 2). Each filter is accompanied by its absorption spectrum. Commercial colored plastic wrap (3-5 layers) may be substituted.

Solution spectra can also be projected on the OHP spectrometer. For best results, the bottom of the glass container must be as optically clear as possible. Beakers will do, but petri dishes are flatter and better. Absorption bands of food colorings show up most clearly for solutions made by fourfold dilution of dye with water. A volume of 20 mL provides a path length of 0.5 cm in a 10-cm petri dish. Observing the spectrum of a chlorophyll solution can be used to demonstrate how plants capture energy from the sun. The green pigment is extracted by mixing about fifteen medium sized leaves of spinach with 200 mL alcohol. The strong absorption in the blue region (Soret) can be seen at a path length from 0.5 to 1 cm. The peak in the red is too weak to see clearly.

### **Properties of Liquids**

Properties such as adhesion to glass, rate of evaporation, and solubility in water are easily seen on the OHP.

### *Adhesive and Cohesive Forces*

The behavior of water in contact with glass is compared to that of ethanol (Table 2) by placing a few drops of each of the liquids directly onto the OHP glass. The water drop is tight and stable [9] since the attractive forces among water molecules are greater than those between the water and glass. The ethanol drop spreads out because its intermolecular forces are weaker than those between the alcohol and glass.

### *Boiling Point and Molecular Size*

Boiling points can be estimated by observing how fast liquids evaporate from the warm OHP stage. Compounds with similar structures, such as alcohols, can be used to demonstrate how intermolecular interactions increase with mass, thus leading to higher vapor pressures and higher boiling points. A drop or two of each liquid is put directly on the OHP glass and evaporation rates compared [10,11]. For the difference in evaporation rate on the overhead stage to be obvious, the boiling temperatures must be at least ten degrees apart. For example, methanol (bp 65°C and molar mass of 32) can be seen to evaporate before ethanol (bp 78°C and molar mass of 44).

### *Solubility in Water*

The idea that “like dissolves like” is examined by testing the solubility of polar and nonpolar liquids in water [12-14]. A compound containing an oxygen in its formula is polar and thus soluble in water provided the carbon chain is not too long. For instance, all the alcohols in Table 2 have less than four carbons and are infinitely soluble. Hydrocarbons, such as alkanes, are nonpolar and hence insoluble, appearing as globules when projected.

Whether or not a substance is soluble can have enormous environmental consequences. For example, the formula of the anti-knock agent in gasoline, methyl-*tert*-butylether or MTBE,  $\text{CH}_3\text{OC}(\text{CH}_3)_3$  has five carbon atoms, but is still somewhat water-soluble (about 4 g per 100 g water). Dissolving of MTBE in ground water has created serious environmental problems that will require costly remediation.

### **Nature of Acids and Bases**

Many chemical reactions and metabolic processes are extremely sensitive to the acidity of the fluid in which they occur. Acid rain can produce devastating environmental effects. Properties of acids and bases can be demonstrated on the OHP using household materials. Acids

release hydrogen gas upon reaction with common metals. The pH of acids and bases can be measured by using anthocyanin in red cabbage to give vivid colors. Weak acids (or bases) are compared to strong ones, and buffered solutions to non-buffered solutions [15-17].

### *Acids with Metals*

Bubbles of hydrogen gas ( $H_2$ ) appear when certain metals react with 6M hydrochloric acid (20% muriatic acid). In addition to demonstrating typical behavior of some acids, this reaction can be used to compare metal reactivity and thus to create an activity series. Similar amounts of Al, Zn, Fe and Cu (Table 2) are placed in acid, then arranged according to their reactivity. Al reacts most vigorously, then Zn followed by Fe. Cu does not react.

### *Measuring pH*

Concentrated red cabbage extract gives vivid colors for the pH ranges: 1-3 (red), 4-6 (pink), 7 (violet), 8 (blue), 9 (blue-green), 10-12 (green) and > 12 yellow. Anthocyanin, the universal indicator in red cabbage, is extracted by mixing 500 g finely chopped cabbage with 1L rubbing alcohol. After boiling for an hour, the mixture is filtered, then reduced leaving 50-100 mL of deep purplish-black extract which keeps for a few weeks upon refrigeration.

The volume of indicator needed to produce sufficiently bright colors is about one drop per one mL of test solution. Among the common household products to test (Table 2) are vinegar (pH 2-3), baking soda (pH 8), washing soda (pH 9), ammonia (pH 11-12), and lye (pH >12).

### *Strong vs. Weak Acids (or Bases)*

The pH values for the same concentrations of hydrochloric (strong) and acetic acid (weak) are compared. Muriatic acid (20% HCl) is diluted 500 to 1, and vinegar 100 to 1 to prepare 0.01M solutions of both acids. The strong acid, HCl, has a pH of 2 (red) compared to the weak acetic acid with pH between 3 and 4 (pink). Likewise 0.01 M solutions are prepared for the strong NaOH (100 fold dilution of a 1M or 4% solution) and the weak  $NH_3$  (100 fold dilution of the cleaning product). The NaOH has a pH of 12 (yellow) compared to 11 (green) for the same concentration of the weak base,  $NH_3$ .

### *Buffer Action*

Buffers that resist pH changes are essential in living systems. Adding about 4 g NaOH to 200 mL vinegar is an easy way to prepare 1M acetic acid/sodium acetate buffer solution which

has a pH of 4.8. When compared to plain water, the behavior of this solution upon addition of strong acid or base (0.1M made by diluting 20% muriatic acid 50 to 1) is dramatic.

To perform the demonstration, three beakers are placed on the OHP, one blank containing water and two with buffer. Indicator is added. A few drops of 0.1M HCl are placed in the water sample and in the buffer. The pH of the water plummets several units, changing the color from violet to red. The pH decrease of the buffer is so small that it appears unchanged from the original pinkish color. With the addition of a base such as 0.1 M NaOH, the pH of the plain water increases several units turning the indicator from neutral violet to greenish blue. Once again, the pinkish color of the buffer changes imperceptibly when the NaOH is added.

## Conclusion

A few of the many topics that can be brought to life using OHP demonstrations have been described here. Most demonstrations like these can be accompanied by the writing of definitions, formulas, or equations on transparencies. ■

## References

- [1] L.H. Bowman, "A simple, effective introduction to the Beer-Lambert relationships," *J. Chem. Educ.* **59** (1982) 154.
- [2] G. F. Hambly, "Optical activity," *J. Chem. Educ.* **65** (1988) 623.
- [3] J.W. Hill, "An overhead projection demonstration of optical activity," *J. Chem. Educ.* **50** (1973) 574.
- [4] J.E. Fernandez, "A simple demonstration of optical activity," *J. Chem. Educ.* **53** (1976) 508.
- [5] R.B. Goldsmith, "A simple Tyndall effect experiment (OP)," *J. Chem. Educ.* **65** (1988) 623.
- [6] D.H. Alman and F.W. Billmeyer, Jr., "A simple system for demonstrations in spectroscopy," *J. Chem. Educ.* **53** (1976) 166.
- [7] J.D. Martin, "A visible spectrometer," *J. Chem. Educ.* **67** (1990) 1061.
- [8] S. Solomon, C. Hur, A. Lee, and K. Smith, "Spectroscopy on the Overhead Projector," *J. Chem. Educ.* **71** (1994) 250.
- [9] T.P. Silverstein, "Polarity, miscibility, and surface tension of liquids," *J. Chem. Educ.* **70** (1993) 253.
- [10] A. Stenmark, "Which will evaporate first?" *J. Chem. Educ.* **64** (1987) 351.
- [11] E. Boschmann, "Physical and chemical properties," *J. Chem. Educ.* **64** (1987) 891.
- [12] B.H. Nordstrom and K.H. Lothrop, "The effect of polarity on solubility," *J. Chem. Educ.* **61** (1984) 1009.
- [13] W.L. Smith, "Selective solubility: 'Like dissolves like,'" *J. Chem. Educ.* **54** (1977) 228.
- [14] W. Bergquist, "Do 'likes dissolve likes?' An illustration of polar and nonpolar solvents," *J. Chem. Educ.* **69** (1992) 158.
- [15] S. Solomon and N. High, "pH measurements on the overhead projector (OP)," *J. Chem. Educ.* **64** (1987) 964.
- [16] C.E. Ophardt, "Buffer demonstrations," *J. Chem. Educ.* **62** (1985) 608.
- [17] J.J. Fortman and K.M. Stubbs, "Demonstrations with red cabbage indicator," *J. Chem. Educ.* **69** (1992) 66.

Table 1 Materials

Material /Device	Source
Diffraction grating	Project Star Learning Technologies Inc, 59 Walden St., Cambridge, MA 02140 Catalog No: PS-08A (9 in by 5 in) or PS-08B (6 ft x 5 in) 750 lines/mm.
Plastic wrap (teal and rose)	Reynolds® plastic wrap
Filter Color Book of 100	Stock Number NT39-417, Edmund Scientific <a href="http://www.edsci.com/">http://www.edsci.com/</a> 101 East Gloucester Pike, Barrington, NJ/A 08007-1380
Polarizer Film 8.5" x 15"	Stock Number , Edmund Scientific NT45-668 \$28.80
Polarizer Film 8.5" x 5"	Stock Number , Edmund Scientific NT45-669 \$14.70

Table 2 Chemicals and Sources

Substance	Source
Aluminum	foil
Iron	steel wool (soapless), nails, staples
Zinc	dry cell battery can, pennies (after 1982)
Copper	electrical wire, scrub pad, pennies (before 1982)
Ammonia(aq)	ammonia cleaning solution products
Ethanol	denatured ethanol
Isopropyl alcohol	rubbing alcohol
Methanol	Sterno® (4%)
Alkanes (9 to 12 C's)	Goo Gone® spot remover
Anthocyanin	red cabbage
Hydrochloric acid	muriatic acid (20% )
Food Dyes	McCormack®
Sodium bicarbonate	baking soda
Sodium carbonate	washing soda†
Sodium chloride	table salt
Sodium hydroxide	lye; drain cleaner
Chlorophyll	spinach
Sucrose	table sugar

† Generic brands contain much less sodium carbonate than the Arm & Hammer® brand.



## EDUCATIONAL RESEARCH ABSTRACTS

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Editors' Note: As noted in previous issues of the *Journal of Mathematics and Science: Collaborative Explorations*, the purpose of this Educational Research Abstract section is to present current published research on issues relevant to math and science teaching at both the K-12 and college levels. Because educational research articles are published in so many different academic journals, it is a rare public school teacher or college professor who reads all the recent published reports on a particular instructional technique or curricular advancement. Indeed, the uniqueness of various pedagogical strategies has been tacitly acknowledged by the creation of individual journals dedicated to teaching in a specific discipline. Yet many of the insights gained in teaching certain physics concepts, biological principles, or computer science algorithms can have generalizability and value for those teaching in other fields or with different types of students.

In this review, the focus is on “action research.” Abstracts are presented according to a question examined in the published articles. Hopefully, such a format will trigger your interest in how you might undertake an action research study in your own teaching situation. The abstracts presented here are not intended to be exhaustive, but rather a representative sampling of recent journal articles. Please feel free to identify other useful research articles on a particular theme or to suggest future teaching or learning themes to be examined. Please send your comments and ideas via e-mail to gmbass@wm.edu or by regular mail to The College of William and Mary, P.O. Box 8795, Williamsburg, VA 23185-8795.

### Action Research in Your Own Classroom

**Where the action is!** What images from your past does that phrase invoke? For today’s senior citizens it might be World War II, a good paying job, and a house in the suburbs. For middle age Baby Boomers that cry may summon memories of social activism, Dustin Hoffman’s introduction to “plastics,” Woodstock, or carefree summer days at the beach—they might even remember the Dick Clark TV show of the same name! For Generation X, their action expanded from MTV into Wall Street investment banking. And where else could the action be for today’s Generation Y but the Internet and Dot Com enterprises?

Yet for all age groups who happen to be in the teaching enterprise, the action is really to be found in only one place—the classroom. From the kindergarten teacher of five-year-olds to the college professor of graduate students, all teachers act in a classroom to enhance the learning of their students. Most typically, that classroom is a physical space where the teacher and students



interact face to face. However, a “classroom” connection can also be made through teacher-student correspondence (traditional or electronic) and through students’ engagements with exciting, informative materials (books, media, labs, and high-tech teaching technologies).

No matter where that classroom is, the dedicated teacher constantly tries to improve that learning link between the students and the subject matter. One systematic way to do that is through a kind of inquiry known as Action Research (also referred to as “teacher-as-researcher,” “teacher-researcher,” and “classroom-based research”). As David Kember describes it in his book, *Action Learning and Action Research*, “action research is:

- concerned with social practice;
- aimed toward improvement;
- a cyclical process;
- pursued by systematic enquiry;
- a reflective process;
- participative;
- determined by the practitioners.” (p. 24)

Essentially, action research is a teacher’s careful look at students at work in one particular classroom (usually his or her own!). The teacher-researcher systematically collects data, analyzes it, and reflects on what it says about the teaching-learning process in that class. While such action research is intended to be very personalized to a certain group of students in a specific class at one precise time, it may sometimes provide valuable insights that may prove helpful to other teachers as well.

The following articles describe different kinds of action research carried out by teachers in a variety of classroom settings. What those teachers did and what they discovered may encourage you to try action research in your own teaching. What worked for them might work for you, but remember the old TV commercial caution, “Individual results may vary.” Not all research findings about teaching and learning will generalize to the uniqueness of your teaching situation. Yet when it comes to understanding what works best in your own classroom, give action research a chance, for that is truly “where the action is.”

### Action Research in College-Level Courses

- **How might replacing traditional assessment practices with portfolio assessment affect students in a college physics course?**

The use of student work portfolios to document learning has been one of the main recommendations of the assessment reform movement. Instead of evaluating students' learning through objective paper-and-pencil examinations, these reformers want students to provide a collection of evidence that shows their learning. Such a portfolio might contain student essays about concepts learned, journal entries on the importance or usefulness of course topics, homework assignments, relevant laboratory reports, study guide quizzes, short research reports, in-depth analyses of course-related phenomena, or any student work that demonstrates evidence of learning. Unfortunately, the empirical evidence for using portfolios in college-level science courses has been lacking.

Slater, Ryan, and Samson undertook action research in two sections of an algebra-based introductory college physics course to measure the impact of portfolio assessment compared to traditional assessment. Both sections were taught by the same instructor (Slater) and contained sixteen and nineteen undergraduate students respectively. The section of sixteen students was randomly chosen to be evaluated using portfolio assessment while the other section had three tests with traditional multi-part problems and short essay questions as the primary assessment procedure. A pre-test/post-test self-report survey of student perceptions of achievement was given to all students, along with a comprehensive final examination of 24 multiple-choice items matched to the 24 course learning objectives. Most of these items involved calculation since the test was given as an open-book, open-note, open-portfolio exam. Analysis of the results showed no significant differences between the two sections of students. Slater, Ryan, and Samson concluded that a portfolio assessment approach supported learning in a college-level physics course at the same level as did more traditional assessment. In a focus group discussion with students after the course, they found that students in the portfolio section felt less anxiety about learning physics, spent more time outside of class reading and studying physics, personalized the course material more, and enjoyed the learning experience more than students in the traditional assessment section.

T. Slater, J. Ryan, and S. Samson, "Impact and Dynamics of Portfolio Assessment and Traditional Assessment in a College Physics Course," *Journal of Research in Science Teaching*, 34(3) (1997) 255-271.

- **What difference does it make in the way a teacher models physics problem-solving for students?**

A traditional part of every physics course is having students solve problems. Bob Kibble writes about one particular problem he gave his students to solve: “Janet and her brother decided to race along to the end of their street and back again. The street was eighty meters long. Janet ran at  $2.5 \text{ m s}^{-1}$  while John’s speed was  $1.5 \text{ m s}^{-1}$ . Where were they when they passed each other?” Kibble reports he received correct solutions from eight students, but when he examined their approaches, he discovered six different methods of solution (using a table, using a graph, using relative speed, using ratios, and two different algebraic solutions). He acknowledged that he might generally first think of a mathematical approach whereas others might find pictorial or conceptual methods more effective. A teacher could use action research to monitor and categorize students’ problem-solving strategies in order to acknowledge the variety of legitimate ways to think about and solve problems.

B. Kibble, “How Do You Approach a Physics Problem?” *Teaching Physics*, **34**(1) (1999) 16-18.

- **How well does a cooperative learning strategy work with physics students?**

Most experienced physics teachers reluctantly concede that neither an excellent lecture nor a good set of textbook problems will necessarily lead their students to a clear understanding of key physics concepts. So what’s a teacher to do? A group of physics professors in Australia have tried a cooperative learning strategy called the Conceptual Understanding Programme (CUP). Three or four students of mixed ability form a group that works on physics concepts in real-life situations. The students first think about the situation on their own and then they work together as a team. Students are encouraged to use diagrams to describe their thinking so that they can represent relative sizes and relationships of physical objects without calculations. During the subsequent discussions, the instructor facilitates communication among teams and helps the students work toward a consensus view of the situation. Four of these one-hour sessions were held throughout the semester.

Students were interviewed, the CUP sessions observed, and a follow-up survey administered as part of an evaluation of this cooperative learning strategy. Mills, *et al* report that students using the CUP approach showed a high level of enthusiasm, a feeling of being recognized as individuals, an awareness of the value of understanding concepts, and an awareness of how they were learning. While these action researchers acknowledge that some students were cautious about the value of the small group sessions—most usually “shy” students, students with

insecurities about their physics knowledge, students from different backgrounds than the majority of students, or students who wanted to find a “final answer” through formulas and quantitative calculations—they also affirm the value of these CUP sessions to enhance the conceptual understanding of difficult physics ideas for a majority of students.

D. Mills, B. McKittrick, P. Mulhall, and S. Feteris, “CUP: Cooperative Learning that Works,” *Teaching Physics*, **34**(1) (1999) 11-16.

- **What reform teaching strategies benefit the higher-order thinking skills of organic chemistry students?**

Higher-order cognitive skills (HOCS) such as question asking, problem solving, decision making, critical thinking, and evaluative thinking have often been distinguished from lower-order cognitive skills (LOCS) such as remembering, comprehending, and applying memorized algorithms. While HOCS is a worthy goal for college science courses, many professors are gratified to see their students reach a proficiency level for LOCS about the subject matter. Zoller argues that higher-order thinking can be achieved if faculty make the effort to teach and assess with an HOCS emphasis. He supports his view by reporting two international efforts in organic chemistry courses in Israel and Canada.

In both the small organic chemistry course in Israel (class size of 31 students) and the large class in Canada (152 students), the instructors used an inquiry approach in which they raised questions rather than simply providing explanations. For example, this is one of the questions used to initiate class discussion, “An acid-catalyzed addition of  $D_2O$  to propene would give an alcohol. Do you expect the product to be optically active? Explain.” They also used higher-order thinking test items than would be found in a traditional organic chemistry course. For example on the midterm exam, they asked this question, “The hydrolysis of esters is based on the reversibility of the esterification reaction. Which of the following esters do you expect to hydrolyze faster in an alkaline hydrolysis and why? Explain. [Two different chemical compounds were shown underneath the question.]”

Zoller used students’ performance on both HOCS and LOCS test questions and conversations with students to evaluate the effectiveness of this inquiry teaching strategy. He concluded that students’ exam performance showed the approach to be feasible and effective in both small and large chemistry classes. He acknowledged the legitimacy of faculty concerns that there is insufficient time for full coverage of all course topics using an inquiry approach and that

some students will prefer a traditional teaching approach of lecture and test. Zoller also admitted that HOCS assessment in large classes is “a very tedious, lengthy, and time-consuming task.” Nevertheless, he believes that an HOCS orientation in chemistry better prepares students for real life thinking outside the classroom rather than does a LOCS-type final exam. Through instructional innovations such as peer grading, instructor practice with Socratic questioning, and guidance in better test item construction, Zoller believes HOCS-fostering pedagogies can be creatively implemented in college chemistry courses.

U. Zoller, “Scaling-Up of Higher-Order Cognitive Skills-Oriented College Chemistry Teaching: An Action-Oriented Research,” *Journal of Research in Science Teaching*, **36**(5) (1999) 583-596.

• **What is the impact of using concept maps and interpretive essays in undergraduate mathematics classes?**

So draw me a picture? One way students might show what they understand about a topic is to draw a concept map (also known as a “graphic organizer” or “web”). A concept map is a graphical illustration of concepts to form chains of relationships. Typically, each concept is represented by a node with a line and linking words connecting the nodes to indicate specific relationships. In an action research study with her own students, Linda Bolte describes how such concept maps and writing accompanying interpretive essays might be used to assess students’ organization of mathematical knowledge.

Bolte taught 27 prospective elementary teachers enrolled in a required mathematics content course, eighteen prospective secondary mathematics teachers in a required geometry course, and 63 students enrolled in two sections of *Calculus I* how to construct concept maps. She illustrated the various steps in constructing a concept map with a variety of familiar mathematical terms and gave students practice in arranging and linking the various terms. Once students had completed their concept maps, they wrote an essay that clarified the relationships portrayed in the concept map.

Bolte evaluated the effect of the concept maps and essays through the use of a holistic scoring criteria that focused on the organization and accuracy of the concept map and the communication, organization, and mechanics of the essay. She discovered that the concept map/essay scores were more highly correlated with final grades than the combined homework and quiz scores in three of her four classes. She also reported that the concept map and essays allowed her to identify student misconceptions and students’ mathematical knowledge better than

through a more traditional measure on homework and examination problems. Students reported that the concept maps/interpretive essays helped them reflect on their work in a more explicit manner, encouraged them to modify and extend their mathematical knowledge, and allowed them to think about mathematics as a more creative activity. Bolte believes her experience should encourage other mathematics teachers to use concept maps and interpretive essays because they involve significant mathematics, accommodate individual student differences, require effective student communication, and motivate students' best performance.

L. Bolte, "Using Concept Maps and Interpretive Essays for Assessment in Mathematics," *School Science and Mathematics*. 99(1) (1999) 19-25.

- **How might a special problems physics course be used to introduce pre-service elementary students to the practices and discourse of science they would later use with their own students?**

Smith and Anderson designed a physics course in which future teachers would have a real opportunity to: (a) invent models and theories to explain and predict phenomena; (b) design, gather, and interpret data; (c) consider authoritative sources and evaluate their validity claims within a community of discourse where knowledge claims are publicly debated. Nine seniors in a five-year elementary teacher preparation program were enrolled in the course. A semi-structured interview about these students' science learning experiences and their views about science was conducted with all nine students either at the beginning or end of the course. During the course, the instructor and students kept journals and all class sessions were videotaped. Two graduate research assistants met weekly with the instructor to discuss students' progress and class experiences.

Using the physics of light as the focal topic in the course, the instructor had students read storybooks which raised interesting scientific questions. They would share ideas about the physics involved in the story situation and discuss ways to find out answers and test out student ideas. In small groups, they would design specific experiments and make models to represent or explore emerging theories. The whole class would come together to share their work and discuss outside readings and the validity of scientific claims. A central theme in the course was the role of discourse in scientific practice. Stories about scientists' disagreements about models of light highlighted the roles that discourse, publication, and the larger scientific community played in validating claims (p. 758).

At the beginning of the course, Smith and Anderson discovered that students started the course with different attitudes about science and science learning. The “knowers” were successful science learners who focused on facts, getting the right answer, and conformity with the trusted authority of textbooks and professors. The “wonderers” were unsuccessful science learners who valued their personal experiences and beliefs and seldom made appeals to scientific authorities. By the end of the course, both sets of students had expanded their views of the roles of models, data, and authority in the generation and validation of scientific knowledge. The students also showed a decline in faith in authority and a more complex understanding of the nature and value of authoritative sources. The search for logical connections among the models and data replaced students’ habitual acceptance or rejection of authoritative scientific knowledge. Smith and Anderson argue that providing such reform-based course experiences can result in “elementary teachers who bring solid conceptual understanding as well as sophisticated sociocultural views of science to their work with children.” (p. 774)

D. Smith and C. Anderson, “Appropriating Scientific Practices and Discourses with Future Elementary Teachers,” *Journal of Research in Science Teaching*, 36(7) (1999) 755-776.

### **Action Research in K-8 Classes**

- **What experiences prepare fifth grade students to understand the multiplication of fractions?**

How can a teacher best help students understand “taking a part of a part of a whole” in a meaningful way? Nancy Mack suggests a three step approach any teacher can use in her own class: “What mathematics do I want students to learn?; What informal knowledge do students have?; How might I help students build on their informal knowledge?” (p.34) With respect to multiplication of fractions, a teacher might want her students to be able to solve problems such as, “You have one-half of a giant chocolate chip cookie. You give your friend one-fourth of the piece you have. How much of the whole cookie did you give your friend?” [Mandated grade-level curriculum guides or a school system’s learning objectives will often identify the mathematics you are supposed to teach. Nevertheless, the revised NCTM standards, as well as your own classroom wisdom, should broaden your decision about what mathematics students need to know to accomplish the state standards!]

Mack suggests a series of questions to assess the informal knowledge of students about multiplying fractions. “There are eight cookies on a plate. Three people want to share all the

cookies. How many cookies will each person get?" Look how each child tries to solve that problem. Let them draw diagrams. Let them act out the answer with "pretend" cookies. Let them even work with numbers if they want. Next, ask students to explain the meaning of a fraction. Then, give them the problem of finding one-fourth of one-half of a cookie. Mack believes all these approaches will give the teacher a more accurate diagnosis of each student's informal knowledge that can guide her instructional decisions.

Once a student's current level of understanding is assessed, the teacher can introduce a sequence of activities to build on that knowledge. Mack suggests starting with equal-sharing situations such as sharing eight cookies among three people. Then students can be asked to find a fraction of a whole number before tackling the "part of a part of a whole" situation such as finding one-fourth of four-fifths of a cookie. Throughout her article Mack encourages teachers to apply action research to their lessons. Keep track of what children do to solve your problems. Look at the kinds of diagrams they use to explain their ideas. Keep a notebook of their responses and your observations. Use the diagrams they draw to help the students connect to number sentences involving multiplication of fractions. Assess the effectiveness of your instructional activities with students having different informal knowledge of multiplying fractions.

N. Mack, "Building a Foundation for Understanding the Multiplication of Fractions," *Teaching Children Mathematics*, 5(1) (1998) 34-38.

- **How can you enhance the geometry concept learning of elementary school students?**

Geometry is a course that some states are now requiring for high school graduation, but geometric understanding does not start in ninth or tenth grade. NCTM standards stress that the conceptual basis of key mathematical ideas begins in the early elementary grades. Fuys and Liebov recommend two different ways to teach geometric figures and suggest teachers systematically examine the effects of these different instructional practices with their own students.

One approach to geometry concept learning is the use of "best examples." Students are shown examples that clearly demonstrate variations in the attributes of the selected concept. For instance, equilateral triangles or hexagons can help students understand regular polygons, especially if these geometric figures are presented in multiple ways (everyday objects, manipulatives, diagrams, verbal definitions).



Another concept learning instructional approach is to use “concept cards” in which examples and non-examples of two-dimensional and three-dimensional geometric shapes are shown to students. Students can use either a prototype strategy (their “average representation” of key features) or a rule-based strategy (their understanding of key properties of figures) to categorize new examples. Students can do this individually, in small groups, or in a teacher-led whole class lesson.

Fuys and Liebov encourage teachers to undertake action research when using different concept learning strategies. They believe both approaches have value whether taught in expository or inquiry lessons, but they more strongly believe that teachers must discover for themselves which students learn better with which method. Teachers should try both a “best example” and “examples/non-examples” approach with their students. If they keep accurate records of each student’s progress, they should be able to discover whether one teaching method is generally more effective or whether individual differences among their students result in both methods helping different types of students to learn their geometric shapes.

D. Fuys and A. Liebov, “Concept Learning in Geometry,” *Teaching Children Mathematics*, 3(5) (1997) 248-251.

- **How are middle school teachers doing “action research” like seventh grade students doing “authentic science?”**

Almost sounds like a riddle, doesn’t it? Bencze and Hodson however are very serious when they make that analogy. They believe certain myths about scientific inquiry are still taught in school:

- Science starts with observation
- Science proceeds via induction
- Experiments are decisive
- Scientific inquiry is a simple, algorithmic procedure
- Science is a value-free activity

Now substitute “curriculum knowledge” for science, “student activities” for experiments, and “curriculum development” for scientific inquiry. The resulting statements are still myths. What does it take to help teachers become curriculum makers rather than just curriculum implementers?

A Canadian researcher (Bencze) and two teachers collaborated to develop and implement a more authentic seventh grade science curriculum. The researcher encouraged the teachers to repeat cycles of: (a) reflecting on and challenging each other's beliefs and practices; (b) seeking and critiquing alternative views to develop new approaches; and, (c) field testing and evaluating these approaches in their classrooms. The teachers developed more open-ended scientific investigations for students where designing a variety of scientific inquiries, thinking about variables, and interpreting findings were more important than merely duplicating the textbook-derived "correct answer." Both the students and the teachers became more independent thinkers about the scientific process and less accepting of the common myths about science.

One of the main goals of this authentic science curriculum is to help students and teachers expand their idea of scientific inquiry from pure experiments to correlational and practical field-based studies. Bencze and Hodson report that this new kind of science curriculum helped students "reflect on what causal relationships may exist in a system, plan appropriate action to bring about a desired change, implement that action, and evaluate its effectiveness. Within the action research group, teachers behave similarly. Action research is also based on the premise that understanding can result from action." (p. 536) While Bencze and Hodson admit the teachers felt they never had enough time to accomplish all the curriculum reform they wanted, these researchers also proclaim that systematic action research during everyday teaching does allow teachers to reassess their own views and practices in the most meaningful way.

L. Bencze and D. Hodson, "Changing Practice by Changing Practice: Toward More Authentic Science and Science Curriculum Development," *Journal of Research in Science Teaching*, 36(5) (1999) 521-539.

### Action Research in College Courses for Pre-Service Teachers

- **What are the advantages and disadvantages in using an oral performance assessment in a mathematics methods course?**

Write it or say it? What is the best way to determine what your students have learned? The reform movement in mathematics and science recognizes that changes in instructional techniques and pedagogical strategies must be accomplished by changes in assessment procedures. If classroom teachers are expected to use a variety of assessment techniques with

their students, then college professors should model these procedures in college level teaching methods courses.

Denisse Thompson believes so strongly in that philosophy that she implemented an oral performance assessment into her mathematics methods course. Because much attention was given in her methods courses to the development of mathematics concepts through the use of manipulatives, she wanted to go beyond written exams in assessing her students' ability to explain those concepts. At the beginning of the year, students were given guidelines for the oral performance with a list of tasks (e.g., "Illustrate the meanings of perimeter and area using pattern blocks"; "Demonstrate congruence and similarity using a geoboard"; "Illustrate the meaning of surface area using blocks"; "Illustrate the Triangle Inequality Theorem using straws.") At the end of the semester, each elementary methods student was scheduled for a twenty minute interview in which she would be given five randomly chosen tasks to demonstrate. Each task was graded on a ten-point scale to reflect both appropriateness of each student's answer and need for prompting from the instructor.

Thompson used both her students' and her own reflections about this oral performance assessment. She believes it has the advantage of allowing the instructor to probe for greater depth of student understanding than on written tests, to remediate misconceptions during the oral interview, and to prompt students for more explanations of a given concept. Students identified the ability to demonstrate mathematical knowledge with manipulatives, the importance of practicing effective communication skills, the one-on-one feedback from the instructor, and the ability to determine their strengths and weaknesses in that interview as the biggest advantages. Students identified being nervous during the interview as the biggest disadvantage. Thompson saw the biggest disadvantage as the amount of time needed to conduct the interviews. However, she believes it is comparable to the instructor time needed for grading essay exams or lesson plans. For Thompson, the advantages far outweigh the disadvantages, and it has the added benefit of modeling alternative math assessment techniques while encouraging pre-service teachers to use such techniques with their own elementary school students. "Educators must practice what they preach or run the risk of having their message fall on unbelieving ears." (p. 88)

D. Thompson, "Using Performance Assessment to Engage Pre-service Teachers in Mathematical Discourse," *School Science and Mathematics*, 99(2) (1999) 84-92.

- **How might a methods of teaching science course be used to introduce pre-service students to becoming a “teacher as researcher?”**

Action research does not just happen. The seed of the idea to do it must be planted, nourished, pruned, and admired. Emily van Zee describes what she did in her methods of teaching science courses between 1995 and 1997 to help students learn how to do research. While her main course goals were to increase the competence and confidence of prospective teachers in teaching science, she also wanted to incorporate research experiences in her courses. Van Zee began her course by having students describe their prior experiences learning science. The students analyzed those experiences that fostered the most positive science learning experiences (e.g., interesting subject matter; hands-on experiments; enthusiastic teacher; allowed to make mistakes). Each week, the students wrote a reflective journal entry about a science learning event they had observed or experienced. They would later reflect on these entries to identify common themes and factors that promote effective science learning. Finally, in their take-home final, the students would recommend science teaching methods based on their observations, connect these claims to science teaching standards, and formulate a research question that could be explored in their own classrooms after they graduated.

Van Zee also used this inquiry approach in exploring science content by focusing on one topic in depth throughout the semester on phases of the moon. Early in the semester, students again indicated what they already knew about the moon and what they would like to discover about it. Throughout the course, students summarized observations, shared patterns observed, and described their models to explain these patterns. The conclusion of this process required students to communicate their current understanding of the phases of the moon as well as the process by which they had reached this opinion. Van Zee also expanded this inquiry technique through field-based assignments where the prospective teachers interviewed children and adults about a particular topic. The students then designed “conversation” (rather than “lesson plans”) that could be used to initiate, facilitate, experience, and assess these science ideas in their school placement settings.

Through instructor reflection, students’ written work, and informal student questionnaires, van Zee concluded that students agreed her teaching methods were a good match to the national standards for science teaching. Many students expressed appreciation for her student-centered approach and its positive impact on their attitudes toward science and science teaching. However, many students complained about the amount of student-centered work and asked for more of the “standard teacher lecture.” Some students do prefer learner-centered

teaching; other students prefer teacher-directed instruction. There is no one best way to induce a love for and understanding of science learning in prospective school teachers. Yet through a commitment to action research, the classroom teacher can connect her teaching beliefs to real life outcomes and find personal meaning in both the product and the process of that research effort.

E. van Zee, "Preparing Teachers as Researchers in Courses on Methods of Teaching Science." *Journal of Research in Science Teaching*, **35**(7) (1998) 791-809.

• **Still not convinced to try some action research? Why else would you conduct action research in your own classroom?**

Lederman and Niess argue that action research can and should be a significant component of both pre-service and in-service teacher programs because it is the most direct route to helping teachers become reflective practitioners. They believe systematic, classroom-based inquiry helps teachers develop a critical eye about their own instructional practices. Investigating classroom instructional and learning actions can sensitize the teacher to the multitude of variables and relationships that impact successful teaching. It also may help teachers see educational research as a valuable contribution to their own understanding, rather than just journal articles of esoteric, theoretical, impractical, over generalized, jargon-filled pages with nothing to say to them. Action research in your own classroom is aimed at the questions you want answered, the issues that will help you become a better teacher with students who become better learners. Action research can speak louder than textbook words when it comes to understanding what works in your own teaching.

N. Lederman and M. Niess, "Action Research: Our Actions May Speak Louder Than Our Words," *School Science and Mathematics*, **97**(8) (1997) 397-399.

**Next Steps!**

For other ideas about the kinds of action research you might try with your own students, look at any research article on a topic of personal interest. What did those researchers do that you might want to try in your own classroom? For example, White and Frederiksen provide an extensive description of the reform teaching strategies of student inquiry, teaching modeling, and metacognitive thinking applied to science. Why not take one aspect of their approach to try in one of your own lessons or units? What do you think might happen? What kinds of data can you collect to test out your expectations? What did you find and what does it mean? Don't wait. Action Research today means Better Teaching tomorrow.

B. White and J. Frederiksen, "Inquiry, Modeling, and Metacognition: Making Science Accessible to All Students," *Cognition and Instruction*, **16**(1) (1998) 3-118.

**Sample Books on Action Research and Teacher-Researcher Research**

G. Burnaford, J. Fischer, and D. Hobson (eds.), *Teachers doing research: The power of action through inquiry*. Erlbaum, Mahwah, NJ, 2001.

Z. Donoahue, M. van Tassell, and L. Patterson (eds.), *Research in the classroom: Talk, texts, and inquiry*. International Reading Association, Newark, DE, 1996.

D. Hopkins, *A teacher's guide to classroom research*, Open University Press, Buckingham, 1993.

R. Hubbard, and B. Power, *Living the questions: A guide for teacher-researchers*, Stenhouse, York, ME, 1999.

D. Kember, *Action learning and action research: Improving the quality of teaching and learning*, Kogan Page, London, 2000.



## **A I M S & S C O P E**

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.

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