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Supporting the K-12 Classroom through University Outreach

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Abstract

This article provides a field-based example of a series of outreach programs that have been designed in response to current recommendations found in the K-12 outreach literature. These programs begin with university mathematics and science faculty members teaching a 10-day summer workshop to elementary and middle school teachers. Following this workshop, a graduate student provides direct classroom support for 15 hours each week throughout the academic year to the participating teachers. At the high school level, graduate students offer after-school mathematics and science enrichment clubs to students. Early findings indicate a positive impact on teacher understanding of mathematics and science as measured by summer workshop pre and post assessments and participating students' development of mathematical knowledge as measured by a standardized test. Additionally, there has been a recent increase in faculty members' willingness to participate in these outreach programs.

Introduction

In mathematics and science, researchers *(Kerachsky, 2008; Kirsch, Braun, Yamamoto, & Sum, 2007; Martin, Mullis, & Chrostowski, 2004; Mullis, Martin, Gonzalez, & Chrostowski, 2004)* have found that U.S. students are performing below many of their international peers in comparable grade levels. According to Kirsch et al. *(2007)* and McMasters *(2006)*, by college few U.S. students are prepared for or interested in pursuing degrees in engineering. In the past, engineering and engineers have played a pivotal role in building U.S. economic capabilities. Professional societies *(National Academies, 2007)* are expressing concerns that under the current conditions the U.S. may not be able to maintain its global competitive edge.

This article provides an example of a sequence of university outreach programs designed to complement each other and to build on the prior research in K-12 outreach. These programs utilize the efforts of graduate students to facilitate communication between university faculty members and the K-12 community. These programs are further designed to reduce the burden placed on K-12 instructors as they seek to identify and develop materials that deepen students' understanding of mathematics and science.

Additionally, this article discusses the factors that appear to contribute to higher education faculty member participation in these outreach programs. The opinions expressed in this article are those of the authors and do not necessarily reflect those of our funders.

We begin with a brief review of the U.S. K-12 system. This is followed by a discussion of the restrictions university systems directly or indirectly place on outreach activities. The section concludes with a review of research concerning effective models for K-12 outreach.

K-12 System

Research indicates that students lose interest in mathematics and science, subjects that provide the foundation for engineering, as early as the middle grades (grades 6 through 8), and this is reflected in students' declining test scores *(Barker & Aspray, 2006; Fennema, 2000; Margolis & Fisher, 2003)*. By high school, many students opt out of higher level mathematics and science *(American Association of University Women, 1992; National Center on Education and the Economy, 2006)*, unknowingly limiting their future career options. Both the Trends in International Mathematics and Science Study (TIMSS) *(Kerachsky, 2008)* and the National Assessment of Educational Progress *(National Center for Educational Statistics, 2008)* found that as U.S. students progress from primary through secondary schools, their average academic performance in these subjects steadily declines. Many competing nations have not reported a similar decline. Researchers *(Hyde, Lindberg, Linn, Ellis, & Williams 2008; Kerachsky, 2008; Mead 2006)* have further reported that in the United States the performance of African American and Hispanic students in mathematics and science lags behind that of Caucasian students. Additionally, students whose families have low incomes are more likely than their financially able peers to perform at the lowest levels *(Kerachsky, 2008)*. Unlike any other period in history, the future competitiveness of the U.S. is dependent on the K-12 education system developing all students' talents in mathematics and science, and in encouraging all students' interests in these areas as well as engineering. No U.S.

"[T]he future competitiveness of the U.S. is dependent on the K-12 education system developing all students' talents in mathematics and science. . ."

subcultures or subpopulations can be left without a strong education in mathematics and science.

The results of standardized tests indicate that students are engaging in mathematical and scientific learning in the elementary years, and it is during these years that students need to be exposed to the exciting applications of these fields. In U.S. elementary schools, teachers need to develop student understanding and interest in mathematics and science while maintaining a focus on reading. Reading provides an essential foundation for all forms of learning. Because of this, mathematical and scientific discoveries in the early years need to be embedded in a literacy-rich environment. Students need continual exposure to simple and exciting texts that address mathematical and scientific content.

By middle school, many students are equipped with basic mathematics skills that can be used to answer scientific questions that surfaced during elementary school investigations. In other words, by middle school an interest in science can provide the stimulus for developing deeper levels of mathematical understanding, much in the same manner that scientists deepen their own mathematical knowledge during scientific exploration. High school becomes a vehicle for feeding students' natural scientific and mathematical curiosity that has been nurtured through the earlier grades.

U.S. teachers, especially at the elementary level, are not equipped with an in-depth knowledge of mathematics, nor do they understand how mathematics, science, and engineering are being applied to the rapidly changing world *(Ball, Lubienski, & Mewborn, 2001; Hill, Rowan, & Ball, 2005; Ma, 1999)*. Their own education was a product of an educational system that emphasized the reproduction of memorized algorithms with few examples of the applications *(Ball et al., 2001)*. Expecting teachers to acquire detailed knowledge of mathematics, science, and engineering in a short period of time across many fields, while continuing to develop mastery of their own field, is both unnecessary and unreasonable. Many scientists struggle with the challenge of staying abreast of their field; teachers cannot be expected to stay abreast of their field as well as that of the mathematicians and scientists. As has been argued elsewhere, improving K-12 education is a shared responsibility between K-12 and higher education institutions *(Lima, 2004; National Academies, 2007)*.

Restrictions in Higher Education

Most administrators and faculty members in higher education institutions would agree that higher education has an obligation to support the improvement of K-12 education *(Lima, 2004; National Academies, 2007)*. Historically, a major barrier to faculty work in K-12 schools is the value placed on outreach activities in the promotion and tenure process. At most universities, promotion and tenure decisions are based on research publications and funding *(Justice, 2006)*. Although most higher education institutions consider outreach consistent with the university mission, these same institutions often do not reward or encourage outreach activities. Academic faculty members who begin their careers with an interest in K-12 outreach soon become entrenched in a system that values and rewards research productivity and prestige. The few faculty members who remain involved in K-12 outreach do so at the risk of reduced recognition and, if their tenure decision has not been made, at the risk of losing their jobs. Senior faculty members often recommend that junior faculty members avoid outreach activities, such as working with K-12 schools. By the time a faculty member completes the tenure process, interest in K-12 outreach is often a faint memory.

Today, however, the National Science Foundation (NSF), a primary funding source for many universities, recommends that university faculty members include K-12 outreach as part of their broader impact statements when submitting a proposal. Researchers may fulfill this obligation through visits to the K-12 classroom or through the development of singular content modules. Untrained faculty members who do not understand the classroom structure may unintentionally place a burden on the classroom teachers by introducing material that is not readily applicable in the standard curriculum. Classroom students may see little relevance in the scientists' visits or may be discouraged by the material the scientist presents. When such presentations are poorly implemented by the visiting faculty members, teachers and students can develop negative attitudes toward mathematics and science. Research indicates that short interventions, even when done well, are unlikely to have impact on the ongoing, day-to-day activities of the classroom *(National Council of Teachers of Mathematics, 2002)*. A more effective approach to outreach is likely to be the development of a collaborative relationship among university faculty members and K-12 teachers over a sustained period of time, such as a year or longer.

Models for University K-12 Outreach

NSF has supported programs in which graduate students, referred to as graduate teaching fellows, rather than members of the faculty, provide academic year support to the K-12 classroom. These programs often begin with a summer workshop in which faculty members, K-12 teachers, and graduate teaching fellows establish a collaborative relationship. Through NSF funding, the graduate students are compensated for their classroom efforts, which consist of up to 15 hours of direct classroom support each week throughout the academic year. Bledsoe, Young-Shin Park, and Gummer *(2004)* have proposed and have studied models for such interventions that are tailored to the elementary, middle, or high school level.

Elementary school level (K-5).

At the elementary level, Bledsoe et al. *(2004)* propose that graduate teaching fellows act as liaisons between teachers within the given school, and between the elementary schools (K-5) and the university. This design is possible primarily due to the structure of the elementary school, in which every teacher provides instruction on many different subjects. Elementary school teachers are generalists, and in this capacity they have a broad base of knowledge that spans the disciplines—literacy, language, art, music, science, mathematics, history, and social studies. A primary benefit of the graduate teaching fellows' participation in the classroom is the content knowledge that they bring to the classroom in mathematics and science. Because elementary teachers spend less time teaching mathematics and science than do middle and high school teachers, a single graduate student can support multiple classrooms. This provides additional benefits. A graduate teaching fellow who is supporting several elementary school teachers can transfer information horizontally across teachers who are instructing the same grade level, and vertically across the participating grade levels. Teachers and graduate students have the opportunity to use lesson plans designed for one grade to inspire instruction at another grade level. Schmidt, Houang, and Cogan *(2002)* have argued that the spiral curriculum in many U.S. schools is often implemented as a circular curriculum. A spiral curriculum is intended to gradually deepen student knowledge, but teachers who are pressed for time frequently address repeated topics with little more depth than in the prior year. Not knowing how the content was addressed in the prior years can result in the teachers' beginning instruction at a basic level, assuming the students have had no previous exposure to the material. With the added pressure of content coverage, many teachers never progress beyond a basic introduction of complex topics.

Trained graduate teaching fellows can facilitate communication between grade levels as they move from classroom to classroom. They can also alleviate the stress of teaching a topic at increasing levels of depth by having the time to ask the teachers of the younger grades how the topic was previously addressed. Another benefit of having graduate students participate in the elementary classroom is that, since it is their job, they have the time to research innovative activities. Teachers often do not have the time to complete online searches for new materials or to review recent literature on a particular learning topic. Graduate students are also familiar with the university system. They can act as liaisons with the university, arranging for classroom visits by faculty members, or for loans of scientific equipment from the university.

Middle school and high school level.

According to Bledsoe et al. *(2004)*, the role of the graduate teaching fellow should be defined differently at the middle school (Grades 6 through 8) and high school (Grades 9 through 12) levels. Middle school and high school teachers provide instruction within one or two content areas, allowing them to develop expertise in these areas. At the middle and high school levels, graduate fellows can be placed with a single teacher, or with two teachers providing instruction at the same grade level and within the same discipline. Sharing a graduate student across multiple teachers and grade levels becomes less feasible, as the instruction of mathematics and science by the given teacher occurs throughout the day. The role of the graduate student at the middle and high school levels is to enhance teachers' knowledge, and to support the development of student knowledge as well as to provide curricular support. As at the elementary level, it is the graduate students who have time to research topics, and to propose hands-on activities for the classroom. Also at this level, the graduate students continue to provide a connection with the university, arranging for classroom visits by scientists, and for loans of scientific equipment.

Summary

In summary, although K-12 and higher education institutions both hold the premise that educating K-12 students is a shared responsibility, neither system has a structure or reward system to support joint efforts. Justice *(2006)* argues that it is the intrinsic rewards, or the desire to make a difference, that catalyze outreach collaborations to form and continue between K-12 institutions and higher education. Effective outreach programs need to capitalize on the synergy offered by K-12 and university partnerships. Faculty members recognize the important contributions that they can make to K-12 instruction; teachers know the K-12 education structure and what works in the classroom.

Outreach Programs at the Colorado School of Mines

In this section, we describe a sequence of outreach programs at the Colorado School of Mines (CSM) that are designed to build on the intrinsic rewards that faculty members experience when they engage in outreach. The authors of this paper, Moskal and Skokan, are the project leaders for these programs. CSM, located in the west, is a school primarily of science and engineering, and has no school of education. The outreach programs described in this article are designed to minimize the time demand placed on faculty members and teachers during the development and implementation process. These programs employ graduate students to facilitate communication between university faculty members and the K-12 community. This section provides a discussion of our funding sources, the participating school districts, and our programs. These programs are based on current literature in K-12 outreach in that they are designed to build on the models proposed in the previous section for elementary, middle, and high school K-12 outreach. We present these programs as examples of how recommendations located in the literature can be transferred to practice.

Funding

Multiple sources of funding support the efforts of CSM. At the elementary level, we receive funding from the Bechtel Foundation for the Bechtel K-5 Educational Excellence Initiative. At the middle school and high school levels, our efforts are primarily supported by the National Science Foundation (NSF) through the GK-12 Learning Partnerships: Creating Problem Centered, Interdisciplinary Learning Environments and the BPC-DP: Broadening Female Participation in Computing: Middle School through Undergraduate Study. We additionally have matching funds to those provided by the Bechtel Foundation from the Renewable Energy Materials Research Science and Engineering Center, Denver Foundation, J. P. Morgan Foundation, Shell Oil Foundation, Boeing Foundation, and ECA Foundation. For our middle and high school programs, we have received additional support from the Tensor Foundation. The total level of funding for the combination of outreach programs is over $1 million per year for the next three years. Teachers at all levels receive honorariums for their efforts, and have the option of receiving continuing education credits. CSM graduate students are compensated through the funding of their stipends, and the payment of their university tuition and fees. These programs provide faculty members with an organized outreach program with which to connect their research.

Elementary and middle school teachers have a classroom resource in the form of a graduate student who has detailed knowledge of mathematics and science, and of the resources available through CSM.

Participating School Districts

Although CSM offers outreach programs in multiple school districts, our primary efforts have been in two school districts. District 1 is 58% Hispanic, 2% African American, 2% Asian, and 38% Caucasian. District 2 is 48% Hispanic, 21% African American, 2% Asian, and 29% Caucasian. Both districts are economically disadvantaged, with a large proportion of students receiving free or reduced-cost lunches (69% in District 1 and 49% in District 2). By concentrating our efforts on two districts, CSM has the opportunity to work intensely with teachers across the grade levels, thus having an impact on the entire K-12 pipeline. Additionally, each of the participating schools was selected because it was classified as low-performing in mathematics or science based on the state's standardized testing system. Currently, we have five participating elementary schools, three middle schools, and two high schools. Additional schools have participated in these programs in prior years.

Outline of Outreach Programs

The Bechtel K-5 Educational Excellence Initiative provides support to kindergarten through fifth grade teachers (elementary school). The GK-12 Learning Partnerships program provides support to sixth through eighth grade teachers (middle school), and the BPC-DP: Broadening Female Participation in Computing program provides support to ninth through 12th grade students. For both our elementary and middle school programs, the participating teachers attend a two-week summer workshop designed to deepen their understanding of mathematics and science as it applies to the concepts of energy and renewable energy. During this program, the teachers meet and begin to develop a professional relationship with the graduate teaching fellows who will provide direct classroom support throughout the academic year. At the high school level, our outreach programs work directly with high school students.

Content Focus

We selected energy, with a specific emphasis on renewable energy, as a key concentration area for this sequence of outreach efforts for the following reasons: (i) interest in energy and renewable energy topics is growing with respect to public concern and research; (ii) sources of renewable energy (i.e., wind, water, and sun) are within the experience base of young children, and are required as part of Colorado's learning standards in science for the fourth grade; (iii) energy and renewable energy concepts are naturally linked with mathematics, science, and engineering at all levels; and (iv) CSM has the appropriate expertise in these areas for sharing with elementary, middle, and high school teachers and students. Additionally, in 2008 NSF funded the Renewable Energy Materials Research Science and Engineering Center (REMRSEC), which has a research focus on the advancement of renewable energy resources. We recruited faculty members from this center to provide their expert knowledge of energy and renewable energy to our K-12 outreach programs. Although many REMRSEC faculty members are tenure track and are concerned with the time demand of outreach, we have constructed a sequence of programs that allows joint efforts among the project directors and participating REMRSEC faculty members, in order to reduce the burden on any given individual.

Summer Workshops

A key component of the outreach is that the elementary and middle school teachers from the two participating school districts complete summer workshops designed to strengthen their content knowledge in mathematics and science. Since 2000, we, the authors, had been offering teacher workshops within our own areas of expertise. This restricted our efforts to mathematics and geophysics for Moskal and Skokan, respectively. Beginning in 2009, we designed a workshop to address energy and renewable energy, areas that were outside our own expertise but aligned with REMRSEC.

Faculty members drawn from mathematics, computer science, physics, and engineering instruct these workshops. Expert mathematics and science teachers drawn from the participating school districts provide pedagogical guidance for workshop design.

As of 2009, participating elementary and middle school teachers within the districts attend a summer workshop 7 hours per day for 10 days. Some sessions are designed to encourage collaboration and exchange of information between elementary and middle school teachers, supporting the vertical exchange of information across grade levels. Other sessions are designed to develop a collaborative relationship among the participating teachers and the graduate students who will provide support in the classroom. All of the workshop activities are hands-on and inquiry based, providing a professional development environment that mimics the environment we seek to support in the classroom *(McCarthy & Bellina, 2002/2003)*. Additionally, ongoing interactions between the teachers at the different grade levels within the same school district support the potential of a spiral curriculum rather than the circular approach of which Schmidt et al. *(2002)* warn.

Graduate students are selected during the spring semester prior to the summer workshops. Each interested graduate student submits an application that includes three letters of support and an essay explaining why he or she is interested in supporting the K-12 classroom during the summer workshop and throughout the academic year. Many of the graduate student applicants are already on campus and know about our programs. We also provide a direct mailing to new graduate students whose application materials indicate prior experience or interest in the K-12 classroom (volunteers in the K-12 classroom, teaching experience, etc.). Both the students' applications and their prior academic record are considered in the final selection process. All graduate teaching fellows attend the summer workshop.

The summer workshops prepare the graduate teaching fellows for the classroom. During approximately 15% of the two-week workshop, the graduate students attend special instructional sessions on student developmental levels, cultural differences in the classroom, and graduate student roles as professionals in the classroom. Expert teachers—teachers identified by the district as having extensive experience or advanced pedagogical knowledge—teach these sessions. The participating graduate students also complete a unit on literacy in the K-12 classroom taught by an expert in literacy. This component of the workshop is designed to prepare graduate students to address the common teacher concern that standardized tests emphasize literacy, and that many students struggle when learning to read, even older students. Our approach is to treat literacy as an integrated component of mathematical and scientific learning. In order to learn mathematics and science, students must be able to read. Through the literacy session, the participating graduate students explore literature that is age-appropriate and that addresses scientific and mathematical content, such as *Amy Loves the Wind (Hoban, 1988)*. In fact, this author has written a series of books that address wind, sun, and rain at the preschool and kindergarten levels, providing an appropriate introduction to renewable sources of energy for the youngest learners.

Academic Year Support

Follow-up activities to the summer workshop include the placement of a graduate teaching fellow in the participating elementary and middle school classrooms for an academic year. At the elementary level, the graduate student is a shared resource, spending a portion of his or her time assisting teachers in the different grade levels (approximately 2 hours per week with each teacher). This design is consistent with the elementary level model proposed by Bledsoe et al. *(2004)*. At the middle school level, the graduate student is placed either full time (15 hours) with a single teacher, or half time (7.5 hours) with two teachers. Whether a graduate student is placed full time or half time depends on the experience level of the graduate student.

Throughout the academic year, the graduate teaching fellows directly support the participating teachers in the classroom. Graduate student efforts include the development and implementation of innovative hands-on mathematics and science instruction that is appropriate to the given grade level. The activities that the graduate students develop are not restricted to energy or renewable energy. Instead, graduate students are encouraged to investigate new areas that are aligned with classroom curriculum. Although we use energy and renewable energy to illustrate mathematical and scientific content and hands-on experimentation during the summer workshop, we do not restrict teachers to the explicit use of these materials. We recognize that each classroom has a required curriculum which it must follow. Our goal is not to infuse energy and renewable energy into the curriculum but rather to encourage teachers to include hands-on learning in the instruction of mathematics and science. The materials that faculty members present during the summer workshop are intended to illustrate such activities, and the graduate students are provided as a classroom resource.

"Our goal is not to infuse energy and renewable energy into the curriculum but rather to encourage teachers to include hands-on learning in the instruction of mathematics and science."

With each activity, the graduate students also research children's books that may complement the mathematics and science being investigated. The graduate students further act as liaisons between the participating faculty and the participating classrooms. They are responsible for assisting the teachers in identifying and inviting appropriate faculty members to visit or participate in the classroom. As part of the larger program, we maintain a list of faculty members who are interested in K-12 outreach. Many of the participating faculty members have expertise outside the realm of energy and renewable energy, but provide expertise in mathematics, science, computer science, and engineering. The graduate students also arrange to borrow university scientific equipment for the classroom, or they arrange field trips to visit the university campus and laboratories.

Within all of the classrooms, the graduate students and faculty recognize the teacher as the expert on curriculum and pedagogy. Although our graduate students complete much of the background research for identifying or developing literacy-rich, hands-on activities, it is the teacher who decides whether these activities are consistent with the curriculum, and whether the activities will be used in the classroom. The teacher directs graduate students throughout the activity development process, and assists the graduate student if the unit is taught in the classroom. This structure supports continuous collaboration among the graduate students and teachers. Through the graduate students, there are also ongoing interactions and collaborations with the participating faculty members.

Summer Camps and After-School Programs

The summer workshops are designed to enrich the participating elementary and middle school teachers' knowledge and understanding of mathematics and science through applications to energy and renewable energy. The participating elementary and middle school students are indirectly affected by the training that their teachers receive and the participation of graduate students in the classroom. Our programs also include components that directly target the knowledge and understanding of middle and high school students.

Middle school.

As part of the outreach program and during the summer, graduate students teach in one-week summer camps for middle school students drawn from the classrooms that participate in the academic year programs. Middle school is the focus of this effort since in middle school many students lose interest in mathematics and science *(Barker & Aspray, 2006; Clewell & Braddock, 2000)*. Through summer camps, we seek to maintain or increase student enthusiasm for mathematics and science. The middle school summer camps, referred to as "Technology Camp," are currently offered in four sessions throughout the summer, one week each. The title of the camp reflects the camps' emphasis on the use of technology in mathematics and science. Up to 25 middle school students attend each camp.

High school.

At the high school level, our outreach efforts are less intense. Due to funding, we cannot place graduate students directly in high school classrooms during the academic year. Also, because the majority of the high school students need summer jobs, we cannot offer summer camps. At the high school level, the graduate students support an after-school club at two participating high schools (one within each district) that focus on recent advances in technology. Because the middle school outreach programs have been in place since 2003 in one of the participating districts, some of the high school students are familiar with our programs.

Indicators of Impact

We use four mechanisms described in the section below to indicate the impact of the CSM programs. The first section describes the pre and post content assessments findings from our summer workshops. The participating faculty members, expert teachers, and an external evaluator collaborate in designing instruments to measure change in the participating teachers' knowledge from the beginning to the end of the summer workshop. The second section describes the external evaluator's observations based on visits to the participating classrooms and interviews with the participating teachers and graduate students. The third section addresses changes in student performance on the mathematics component of the Colorado Student Assessment Program (CSAP), a state-mandated test. The final section tracks the participation of faculty members who have volunteered to participate in our outreach programs over several years.

Unfortunately, a true experimental design with pre and post measures, a control group, and a fully randomized experiment is not possible when working with the public school systems *(Olds, Moskal, & Miller, 2005)*. Most school districts will not randomly place students into treatment and control groups, nor will they deny a subset of students access to a treatment that has the potential for educational benefits. Additionally, these outreach programs are being implemented in school districts that have a large migrant population. In other words, it is unlikely that many of the same students that enter a given grade within a year will exit the same grade in the same district at the end of the year. Given these limitations, the sections that follow should be interpreted as program indicators rather than as experimental results.

Teacher Workshops

During the summer, university faculty members collaborate with expert teachers to instruct a workshop attended by the participating elementary and middle school teachers. For most of the prior workshops, the participating teachers completed multiple-choice pretests that were developed through the collaboration of workshop instructors, expert teachers, and an external evaluator. Example questions from the 2009 instrument are displayed in Figure 1. These pre and post assessments were designed to measure the impact that workshop instruction had on the participating teachers' knowledge and understanding of the content addressed during the workshop. On the last day of the workshop, the teachers completed the same multiple choice questions as a posttest. Table 1 provides a summary of outcomes on these instruments for the periods in which they were administered. As this table indicates, paired t-tests were used to determine whether a statistically significant change was observed from pre- to posttest. Across the four measured years a statistically significant change was found across the six test administrations. The data in Table 1 are reported separately for elementary and middle school teachers; as is reflected through the table, we did not begin working with elementary teachers until the academic year 2008–2009. Based on this table, it can also be observed that over the last six years, we have gradually increased the number of teachers and indirectly the number of students who participate in the program.

Table 1. Attending teachers' performance on pre and post content assessment

				Mean		
Teachers' Level	Year	n	Number of questions on exam	Pre	Post	p-value
Middle	2003-2004	7	20	11	14	.00
Middle	2004-2005	7	25	13	16	.03
Middle	2008-2009	11	25	22	25	.00
Elementary	2008-2009	17	25	17	24	.00
Middle	2009-2010	11	24	13	19	.00
Elementary	2009-2010	16	24	13	21	.00

Figure 1. Sample problems from pre and post teachers' workshop content assessment

Correct answers are labeled with an "*."

Atoms are made of?

(a) Protons and electrons
(b) Protons and neutrons
(c) Protons and neutrons in the nucelus, and electrons spinning around the nucleus*
(d) Protons and electrons in the nucleus, and neutrons spinning around the nucleus

Which process is exothermic?

(a) Melting ice
(b) Melting snow
(c) Condensing water vapor*
(d) Evaporation of water
(e) None of the above

Which of the following is the basic relationship between volts, amps, and ohms?

(a) V = R/I (voltage = resistance/current)
(b) I = R/V (current = resistance/voltage)
(c) R = IV (resistance = current x voltage)
(d) V = I/R (voltage = current/resistance)
(e) I = V/R (current = voltage/resistance)*

Evaluator Observations

Our external evaluator observed each of the participating middle school classrooms at least once every semester and completed focus group interviews with the participating graduate students and their teachers at the end of the academic year. Reflecting on her observations, she stated, "Typically, fellows were actively involved in the classroom activities, creating hands-on activities for the middle school and high school students" *(Westland, 2010, p. 14)*. She also explained, "They [middle school students] associated having a fellow in their classroom with hands-on activities" (material in brackets added by current authors). Examples of such activities can be found both at the GK-12 Learning Partnerships project website (http://mcs.mines.edu/Research/k12-partnership/new/stud.html) and the Bechtel K-5 Educational Excellence Initiative project website (http://mcs.mines.edu/Research/bechtel/new/stud.html). The nature of these activities is illustrated through the following teacher comments *(Westland, 2010)*:

> When my fellow led an activity on how engineers need to consider the properties of materials in the construction of towers. He brought in a variety of items for the kids

> to build towers with and they were challenged to create the tallest and strongest. They had to use their knowledge of properties of solids to do this activity *(p. 11)*.
>
> We did a lesson on measuring electricity use when items are on and off. We then graphed this data. It was a good way for students to validate their predictions and use their math skills to justify their predictions *(p. 11)*.
>
> The impact crater lab was a great success because students needed to use new vocabulary to describe what they saw. There was a high level of engagement with this lab, also. We layered sand, flour and paprika to make the surface of Mars. Using a larger rock to drop into the layers, students drew and described what they saw. Students measured four different distances to determine if distance would affect the depth of the crater. Before we began the lab, one student noticed that another group had a larger rock than his group. He wondered if the size of the rock would make a difference in the depth of the crater. My fellow changed up the lab a bit to include a control group. This is a great example of critical thinking that I want my students to achieve *(p. 12)*.
>
> My lesson was on blood and my fellow introduced a more complex idea to my students (Newtonian vs. Non-Newtonian fluids). Students got to touch/feel types of liquids and discuss which fluid blood was and why. Students enjoyed this and really got to view blood in a new light and gain new understanding of it. My fellow initiated this as my subject was life science and his background was so varied, he easily incorporated other subjects into mine *(p. 14)*.

As these examples illustrate, many of the classroom activities did not address energy or renewable energy. However, throughout these programs and during the summer workshops, the graduate students are encouraged to connect their efforts to the curriculum of the classroom as well as to the graduate student's area of expertise. We used energy and renewable energy during the summer workshops to provide examples of hands-on, literacy-rich activities for the classroom. According to the external evaluator, "The challenge for the fellows was coordinating with the teachers in terms of their curricular needs and the research interests and expertise of the fellows" *(Westland, 2010, p. 14)*.

Student Performances

All students attending public school in Colorado are required to participate in a standardized assessment to measure content knowledge in mathematics, science, reading, and writing. In mathematics, reading, and writing, the state administers the CSAP in Grades 3 through 10. In science, the state administers the CSAP in Grades 5, 8, and 10. Table 2 reflects these requirements, with an X in a column indicating mandated testing within the given subject area within a given grade.

Table 2. CSAP Mandated Testing Requirements
X indicates a mandated test within a given grade level.

Grade Level	Mathematics	Science	Reading	Writing
3	X		X	X
4	X		X	X
5	X	X	X	X
6	X		X	X
7	X		X	X
8	X	X	X	X
9	X		X	X
10	X	X	X	X

Colorado has further developed a student growth model that targets 100% student proficiency in mathematics and reading across grade levels and school districts by 2014. In order to examine the attainment of this goal, 95% of students across Colorado as well as in any given school or subpopulation must complete the CSAP each year. To measure student knowledge growth on an annual basis and evaluate progress toward the attainment of the 100% proficiency requirement for 2014, Colorado currently uses a student growth model in mathematics, reading, and writing. All four of our participating middle schools in 2008 and 2009 were classified by Colorado as having a student growth rate above the 50th percentile in mathematics. In other words, when compared to other schools in the state, all of the participating schools had gains that exceeded the statewide established median. These schools participated in our programs in 2007–2008 and 2008–2009—that is, in the academic years immediately prior to the reported growth scores on the CSAP, this is a positive outcome, given that the participating schools were selected because in prior years they had been classified as underperforming, or beneath the state median. This finding is also important because had the growth rate on the CSAP been judged as insufficient within these schools, our programs would have been closely scrutinized and questioned by the participating districts.

Additionally, two of our elementary schools in 2009 also had a student growth rate in mathematics above the 50th percentile. Both of these schools began participation in the Bechtel K-5 Educational Excellence Initiative in 2008–2009, and the 2009 data reflect the first state measurement following project participation. The third participating school began the program in the 2009–2010 academic year and state data is not yet available for 2010. Since the standardized assessment is not administered in science on a yearly basis, similar measurements are not available for this subject.

Faculty Participation

A measure of impact on faculty members is the change in the number of faculty participants in our outreach programs. In the academic years 2003–2004, 2004–2005, and 2005–2006, we, the authors, planned and implemented the summer workshops with compensation through outreach funds. These workshops were implemented over an 8-day period rather than the originally planned 10-day period due to the exhausting nature of offering such a workshop with only two instructors. No workshop was offered in 2006–2007. In 2007–2008 and 2008–2009, three additional faculty members participated in the instruction of an 8-day summer workshop (five faculty members total). These additional faculty members either were volunteers without compensation or compensated themselves through outreach funds from their own research grants. In 2009–2010, the workshop was extended to 10 days and 26 faculty members participated. The authors of this article were the only members of the faculty compensated through outreach funds. The remaining faculty members either supported themselves through outreach components to their own research grants or volunteered their efforts. A major contributing factor to this increase was the funding of REMRSEC. As part of the REMRSEC proposal, the participating researchers agreed to participate in K-12 outreach. Two additional research teams have made contact during the fall semester (representing two teams of three faculty members each) to discuss the possibility of providing additional support to the summer programs.

How faculty members are recruited to these programs has also changed. Previously, a faculty member with appropriate expertise to participate in our programs would be contacted, and outreach funds would be used to provide faculty members with compensation for their time. Currently, faculty members initiate contact and volunteer their support. A probable major factor contributing to this change is the current NSF recommendation that funded research grants contain an outreach component. In order to fulfill this requirement, faculty members are seeking to connect with K-12 outreach programs.

Conclusion

As is described and illustrated here, the authors have developed and are implementing a structure for K-12 outreach that is based on prior research and spans the K-12 pipeline. Both elementary and middle school programs include fifteen hours per week of direct classroom support by graduate teaching fellows throughout the academic year. As has been recommended by Bledsoe et al. *(2004)*, at the elementary level, graduate teaching fellows act as liaisons between the elementary school and the university. At the middle school level, graduate students are assigned to one or two teachers and seek to enhance the middle school classroom by sharing their content knowledge with both teachers and students. Through these programs, we seek to maintain students' interest and performance in mathematics and science throughout the middle school years, when standardized scores in mathematics and science commonly decline *(Barker & Aspray, 2006; Fennema, 2000; Margolis & Fisher, 2003)*. Our high school programs are optional for students and are designed to further encourage interest and enthusiasm in mathematics and science. By focusing our programs primarily in two school districts, we have had the opportunity to implement programs that span the entire K-12 pipeline within those districts.

Our findings indicate that these programs are having a positive impact on the participating teachers' knowledge and understanding of mathematics and science as measured by the workshop pre- and posttests. Observations completed by our external evaluator indicate that the graduate students are supporting hands-on learning in the classroom. Students' performances on the mathematics component of the CSAP, Colorado's state-mandated test, are improving in the participating districts, and this improvement is at a level that exceeds the median student performance improvement rate for the state of Colorado. Although improvements in standardized test scores cannot be directly attributed to our programs, they do provide an indicator that district-level improvements are being made.

We have also given careful attention throughout the development of our programs to encourage and increase the participation of university faculty members in K-12 outreach. Originally, our outreach efforts were restricted to our own (the authors') efforts to support local school districts. This restricted the content that we could cover to our areas of expertise: mathematics and geophysics. As is the case at most universities *(Justice, 2006)*, tenure and promotion at CSM is primarily based on publications and funding. Many of our faculty members do, however, recognize the value that the NSF places on K-12 outreach efforts. We decided to use this NSF recommendation to encourage faculty members to contribute to our programs. In 2008, we realigned our programs to emphasize energy and renewable energy, an area of increased funding and recognition at CSM. When we began our outreach efforts in 2003, we had two participating faculty members. As of 2009, we had 26 faculty members, the majority of whom were volunteering their time or supporting themselves through their own research funds. We no longer need to recruit faculty members to participate in our summer programs; many faculty members call us and ask to join our outreach programs. Additionally, many faculty members at CSM write the outreach components of their research proposals in collaboration with our programs. This provides faculty members the benefit of connecting with an established effort that is designed to be in alignment with the current literature in K-12 outreach.

"We no longer need to recruit faculty members to participate in our summer programs; many faculty members call us and ask to join our outreach programs."

Our major challenge in the development and implementation of this K-12 outreach structure continues to be funding. We currently have over $1 million in annual funding to support our K-12 outreach activities. A natural question is whether programs such as these be sustained once the current grants come to a close? Although the final answer will not be known until funding ends, we optimistically believe that sustainability is likely. Many members of CSM's faculty directly contact us hoping to connect their research programs to our outreach activities. Each year, members of CSM's faculty write research proposals that include K-12 outreach components with targeted outreach budgets. Much like faculty members' participation in our summer workshops, these commitments continue to grow, and approximately 10% of our annual budget currently comes from such relationships. Despite funding concerns, our plans for the future are to provide outreach programs that span the grade levels within the participating districts, and to adapt our programs to align with cutting-edge, funded research at Colorado School of Mines.

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