

AC 2007-1278: TECHNOLOGY CAMP FOR TEACHERS – BRINGING MULTIDISCIPLINARY ENGINEERING INTO THE MIDDLE SCHOOL CLASSROOM

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Technology for Teachers: Bringing Multidisciplinary Engineering into the Middle School Classroom

Abstract

As part of a three year program funded by the State Department of Education through the No Child Left Behind Act, a two-week summer workshop was held in 2006 for middle school mathematics and science teachers at the Colorado School of Mines. This three year grant, titled “Physical Science in the Middle School Classroom”, was designed to improve middle school teachers’ knowledge of the application of science and mathematics to engineering. During the first two years of this grant, efforts were dedicated to illustrating the physical science and mathematical concepts that are reflected in chemical, electrical, mechanical, civil, and environmental engineering. Topics included heat flow, acid/base reactions, basic electric circuits, graphing, and ratios and proportions. This knowledge was further extended in the third year when participating teachers learned how technology could be used to enhance multidisciplinary instruction. Topics addressed in the third workshop included, “How a Computer Is Built” (computer science, chemical engineering, and electrical engineering), “Robotics” (mechanical and electrical engineering) and “GPS mapping” (computer science, civil and electrical engineering). A group of twenty-five teachers have participated in all three summer offerings as well as the bi-weekly follow-up classroom visits that occur throughout the academic year. Participating teachers report that they value the interaction between the topics of mathematics and science along with engineering and are using multidisciplinary engineering materials in their classrooms. Furthermore, a paired t-test on a pre and post content assessment suggests that significant improvement (a mean score of 16 out of 30 increased to a mean score of 23 out of 30) occurred in teachers’ content knowledge of physical science and mathematics over the course of the workshop.

Introduction

In 2001, the “No Child Left Behind Act”¹ was signed into law in the United States. No Child Left Behind is designed to hold pre-college schools accountable for the academic achievements of their students, and has been cited as the most challenging educational reform act since the Elementary and Secondary Education Act of 1964². States must make certain that all teachers who provide instruction in the core academic subjects of reading, mathematics, and science are “highly qualified” within their respective content area. These requirements have left many practicing teachers struggling to maintain their credentials³.

The Colorado Department of Education has received funding from the federal government for programs that are designed to support mathematics and science teachers in attaining the desired goals of No Child Left Behind. Through this program, partnerships are formed between academic institutions and high-need school districts in science, technology, engineering and mathematics. In 2004, the Colorado School of Mines received funding through this program to support a three-year partnership with

eight local area school districts. The districts were chosen based on their low numbers of highly-qualified mathematics and science teachers or their rural location. Participation in this program by teachers was voluntary. The goals of this program are as follows:

- 1) To provide standards based instruction to students in the middle grade classroom that results in substantial improvement in the students learning of physical science and mathematics as measured by the Colorado State Assessment Program.
- 2) To upgrade the physical science and mathematics subject matter understanding of middle grade teachers through engineering examples.
- 3) To assist teachers in the development of a repertoire of teaching strategies, activities and lesson plans for teaching physical science and mathematics through engineering examples.
- 4) To provide teachers with a sustained experience that aids in continuous improvement and innovation throughout the school year.

To accomplish these goals, the “Physical Sciences in the Middle School Classroom” project was designed to consist of two primary components: 1) a two-week, intensive summer workshop designed to strengthen teachers’ content knowledge in mathematics and science as it applies to engineering, and 2) a bi-weekly follow-up classroom visit throughout the academic year by mathematics, computer science or engineering graduate students. During the first two years of this grant, efforts were dedicated to illustrating the scientific and mathematical concepts that are reflected in chemical, electrical, mechanical, civil, and environmental engineering⁴. Greater details concerning the first two years of this project, including detailed descriptions of the summer workshops, can be found in Tafoya et al.⁴ and Skokan et al.⁵. The focus of this paper is on the third year, in which the participating teachers learned how technology may be used to enhance instruction and how science and mathematics is applied to multidisciplinary engineering systems. This paper provides an overview of the project design and the details of the third summer workshop.

Project Design

As was previously stated, the “Physical Science in the Middle School Classroom” is a three year project that consists of summer workshops for middle school mathematics and science teachers and follow-up classroom visits throughout the academic year. Three workshops have been developed and implemented as part of this project. The objectives of these workshops are displayed in Table 1. Each workshop is designed to be completed by participating teachers in three consecutive summers, with successive workshops building on the concepts that were introduced the previous year. In order to complete the third workshop, the focus of this article, participating teachers were required to have completed the previous two workshops⁵. By the conclusion of the third year, the participating teachers were expected to have obtained all of the objectives displayed in Table 1.

Workshop	Objectives
	Participants will
Common to All Workshops	<ul style="list-style-type: none"> • work in teams to redesign instructional materials in a manner that is appropriate for students
Workshop 1	<ul style="list-style-type: none"> • review graphing principles and apply these principles to physical science in topics such as heat, optics, and forces • learn the operation of sensors such as thermistors, volt-ohm meters, and motion sensors • investigate energy through chemical reactions, heat, waves, and motion • explore physical science concepts of acids/bases, magnetics, and electricity in a mathematics-rich environment
Workshop 2	<ul style="list-style-type: none"> • learn the operation of graphing calculators • apply mathematical principles to physical science topics such as vector arithmetic to projectiles and a trebuchet; trigonometry to waves and RC circuits through construction of an electric piano; and conic sections applied to a solar oven • apply scientific principles to mathematics topics such as density with ratios and proportions, and distillation with volume and percentages
Workshop 3	<ul style="list-style-type: none"> • investigate technology through mathematics and physical science. This includes dissection of a computer, polymer chip construction, Boolean algebra, digital circuitry, and pattern recognition • use technology in real-world applications such as GIS and mapping, and programming and robotics • explore the use of real-time data in mathematics and physical science classrooms

Table 1. Objectives of three year sequence of workshops

Each workshop shares a similar design. Specifically, the workshops are six hours per day for ten consecutive days, not including weekends. During the morning portion, teachers participate in instruction that is specific to their discipline (mathematics or science) and during the afternoon, they participate in a collaborative hands-on project that combines mathematics and science in an engineering activity. This design is consistent with the recommendations of the National Educational Technology Standards which state, “Learning through such multidisciplinary, student-directed learning activities has proved effective and long lasting. New learning environments must provide students with experiences in which they draw upon knowledge from several disciplines, apply a variety of strategies to get at the intended learning, and choose from a rich array of learning tools to examine, publish, illustrate, and communicate their results”⁶.

In order to encourage participating teachers to utilize the knowledge that they gain through the summer workshop, graduate students visit and assist the participating teachers in the classroom throughout the academic year. Each teacher is visited by a graduate student approximately once every two weeks for one class period. The graduate students are drawn from the following fields: Mathematics, Computer Science and Engineering. Graduate students rather than faculty are used for the classroom follow-up for two reasons: 1) graduate students receive less pay than faculty, greatly reducing the project costs and 2) graduate students are easily accepted by the teachers as assistants to the classroom rather than as evaluators of their instructional efforts.

The classroom visits by graduate students serve multiple purposes. For the teachers, these visits provide encouragement to utilize the physical science, mathematics, engineering, and technology content and materials that were examined during the summer workshops in the classroom. They also provide “resident experts” in the classroom who may be used to answer questions both from the teachers and middle school students and an additional set of hands to assist the teacher in classroom implementation. For the middle school students, these visits encourage their teachers to implement interactive and engaging learning environment that connect science, mathematics, engineering, and technology to everyday life and the world around them. The graduate students also frequently assist students who need extra attention to grasp concepts or students who have completed regular assignments and need more challenging work. Furthermore, the graduate students act as mentors and near-peer role models to the middle school students.

Technology Workshop

The focus of the third summer workshop, offered in 2006, was on the use of technology to illustrate multidisciplinary engineering examples in the middle school classroom. The motivation for this workshop came from another funded project, the NSF funded GK-12 Learning Partnerships (DGE 0231611). As part of this project, a group of graduate students developed and implemented a summer technology camp, “Tech Camp”, for middle school students^{7,8}. Tech Camp⁹ has continued for three years with additional funding from the local school district, NSF, Sigma Xi, LexisNexis, Mathematical Association of America Tensor Foundation, the university Mathematics and Computer Science Department, and the university Women in Science, Engineering, and Mathematics office.

Hearing about the middle school camp, the teachers participating in the current project expressed interest— they wanted to learn the same technologies as the middle school students. Based on their request, a two-week summer workshop was developed for middle school mathematics and science teachers. Twenty-five middle school teachers participated in this summer workshop. Seven taught mathematics, thirteen taught science, and five taught both subjects. All had completed the previous two workshops. Table 1 contains the learning objectives for all of the workshops and Table 2 displays the details of the two-week summer schedule for the third workshop.

As Table 2 indicates, participating teachers were exposed to the disciplines of mathematics, computer science, electrical engineering, chemical engineering, mechanical engineering and civil engineering, and to the interaction among these disciplines. Mathematical concepts included exponents (within an emphasis on bases 2, 8 and 16, which are essential in computer technology) and Boolean algebra. Computer science concepts were further reflected through polymer chip technology, programming and global position satellite (GPS) units. Electrical engineering was introduced through a review of resistive circuits and a digital circuit electronics unit. Computer science, mechanical engineering and electrical engineering were all discussed during the construction of Lego Robots. In the GPS mapping unit, the electrical engineering of the

Table 2. Tech Camp for Teachers Program Schedule

Day	Morning Session 9:00-12:00	Afternoon Session 1:00-4:00
Day 1	<ul style="list-style-type: none"> • Introduction, W-2 Forms • Pretest • Google Technology 	<ul style="list-style-type: none"> • Global Positioning Systems and Topographic Mapping
Day 2	<ul style="list-style-type: none"> • <i>Group A:</i> Explore the Inside of a Computer Exponents, Bases, and Memory 	<ul style="list-style-type: none"> • <i>Group B:</i> Review of Circuits & Virtual Electricity-Labs
	<ul style="list-style-type: none"> • <i>Group B:</i> Review of Circuits and V-Labs 	<ul style="list-style-type: none"> • <i>Group A:</i> Explore the Inside of a Computer Exponents, Bases, and Memory
Day 3	<ul style="list-style-type: none"> • Creating an Electromagnet Building a Telegraph • Sending Out an SOS 	<ul style="list-style-type: none"> • Pattern Recognition • Cryptography
Day 4	<ul style="list-style-type: none"> • Polymer Chip Technology 	<ul style="list-style-type: none"> • Trip to IBM
Day 5	<ul style="list-style-type: none"> • Boolean Algebra and Search Systems • Scientific and Library Catalog Research • Effective PowerPoint Techniques 	<ul style="list-style-type: none"> • Presentation Creation • Research Presentations -10min per pair
Day 6	<ul style="list-style-type: none"> • <i>Math:</i> Sense Network 	<ul style="list-style-type: none"> • Digital Circuits • Half-Adders
	<ul style="list-style-type: none"> • <i>Science:</i> Digital Concepts 	
Day 7	<ul style="list-style-type: none"> • <i>Group A:</i> Lego Robots 	<ul style="list-style-type: none"> • <i>Group A:</i> Lego Robots
	<ul style="list-style-type: none"> • <i>Group B:</i> Signal and Image Processing 	<ul style="list-style-type: none"> • <i>Group B:</i> Alice (Computer animation program) Programming
Day 8	<ul style="list-style-type: none"> • <i>Group A:</i> Signal and Image Processing 	<ul style="list-style-type: none"> • <i>Group A:</i> Alice Programming
	<ul style="list-style-type: none"> • <i>Group B:</i> Lego Robots 	<ul style="list-style-type: none"> • <i>Group B:</i> Lego Robots
Day 9	<ul style="list-style-type: none"> • Real-Time Data Analysis for Math and Science 	<ul style="list-style-type: none"> • Technology and Society
Day 10	<ul style="list-style-type: none"> • Evaluation Forms, Purchasing Supplies • Posttest 	<ul style="list-style-type: none"> • LUNCH TO CELEBRATE

satellite transmissions and GPS receiver were investigated. This was combined with a mapping activity with civil engineering applications. The multidisciplinary aspects of complex engineering systems were summarized in the “Technology and Society” session.

To illustrate the hands-on activities that the teachers could utilize in their classroom, the digital circuits activity is described here. During the morning session, the mathematics teachers examined Boolean Algebra concepts, such as AND, OR, NAND, and NOR. This was then linked to a familiar concept: the Google search engine. Simultaneously but in a separate room, the science teachers examined the concepts of integrated circuits and the construction of integrated circuits through the use of polymers. The chemistry of electrical circuitry was also discussed. During the afternoon session, mathematics and science teacher pairs created a half adder. This activity required concepts from both Boolean Algebra and Digital Circuitry, demanding that the mathematics and science teachers work as collaborative teams. By the conclusion of the session, teams of teachers combined their half adders to form a full adder circuit. The activity concluded with a discussion of how computers utilize mathematical operations as part of their basic functions and how topics drawn from mathematics, computer science, electrical engineering, and chemical engineering are all necessary in the development of a half adder.

Assessment

Two methods of summative assessment were used in this project. First, participating teachers completed a 30 question, multiple choice content assessment immediately prior to the summer workshop (pretest) and immediately after that workshop (posttest). The items that comprised the pre and posttest were identical. Example questions from this instrument are displayed in Figure 1 and the interested reader can obtain the complete instrument by contacting the first author. For the purpose of ensuring content and construct validity, the project investigators acted as content experts and constructed a preliminary set of assessment items. An external evaluator reviewed these items and provided feedback for revision purposes based on the psychometric principles of validity and reliability. The mean score on the workshop pretest was 16 out of 30 with a range of 12 to 22. The mean score on the workshop posttest was 23 out of 30 with a range of 17 to 30. Based on a paired t-test, this indicates a statistical significant improvement from pre to posttest ($p=0.000$).

FIGURE 1. SAMPLE QUESTIONS FROM PRE/POST ASSESSMENT

A GPS calculates your position using

- A. concatenation.
- B. triangulation.**
- C. transmutation.
- D. trilobate.

The result of an XOR gate on two Inputs A and B, where A=1 and B=1 is logic

- A. 0.**
- B. 0.5.
- C. 1.
- D. 11.

The second method of evaluation was teacher self-report. At the conclusion of the summer workshop, the teachers completed a university required course evaluation. All teachers reported that they valued the hands-on activities and expected to use these activities their classroom. Half-way through the academic year, the participating teachers were invited to a project meeting at which they completed an open-ended questionnaire. The teachers were asked to identify the workshop activities that they used in their classroom, to identify an area of mathematics or science in which the summer workshop had improved their level of knowledge, and to indicate what the project could do to better support their classroom efforts.

The majority of teachers were able to identify one area of mathematics or science in which the workshop improved their knowledge. In general, the participating science teachers were more likely to report using the multidisciplinary engineering activities in their classroom than were the mathematics teachers. Specifically, all 13 science teachers reported using at least one of the multidisciplinary engineering activities in their classroom; only two of the seven mathematics teachers reported direct use. Five teachers were assigned both mathematics and science classes and all used the materials in their science rather than the mathematics class. In response to this information, the investigators asked the mathematics teachers why the materials were not being used. Their response was that the mathematics curriculum was rigorously defined, leaving little room for the introduction of interdisciplinary topics, and that the pressures of No Child Left Behind required that they rapidly progress through the defined curriculum.

Concluding Remarks

As reflected through the pre and post content assessment results, the participating teachers' knowledge of the presented material did improve over the course of the summer workshop. Furthermore, the self-report data suggests that the majority of the teachers were using these multidisciplinary materials in their classroom. However, mathematics teachers in this study were less likely to find these materials appropriate for classroom use than were science teachers. Based on the teachers' self-report, this result appears to be a

direct outcome of the current design of mathematics curriculum and the pressures of No Child Left Behind.

Mathematics in many schools is treated as a separate subject rather than as tool that has been developed to serve science. In the science classroom, mathematics must be used as a tool. Therefore, the participating science teachers had little resistance to the concept of including mathematics in their classroom. Mathematics teachers, on the other hand, were resistant to using science as a motivator for mathematics. One concern expressed by the mathematics teachers was the inflexibility of the required mathematics curriculum. Another perception was that by including science, progression through the mathematics curriculum would be slowed, an unacceptable trade-off given the pressures of No Child Left Behind.

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