Formative Assessment of the University of South Carolina's Graduate Teaching Fellows in K-12 Education Program

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Abstract

With support from the NSF GK-12 Program, students and faculty in the College of Engineering and Information Technology and the College of Education are working together to (a) improve the teaching and communication skills of engineering graduate students and (b) improve science education in South Carolina schools. This paper describes the project and presents assessment results that are being used to improve the program.

Introduction

The University of South Carolina (USC) received an award from the National Science Foundation's Graduate Teaching Fellows in K-12 Education (GK-12) Program[1] to support fellowships and associated training that will enable graduate students in engineering to serve as resources in K-12 schools. USC is one of over 50 institutions funded by NSF through this program. Some of these awards have been described[2-4], and have provided guidance for the development, implementation and assessment of USC's efforts.

The primary objective of the University of South Carolina's Engineering Fellowships project is to help prepare today's engineering graduate students to be the engineering faculty of tomorrow. To succeed, these graduate students must be prepared to teach to a generation of students that has grown up in a global, high-tech society. To teach these students, tomorrow's engineering faculty needs better communication and teaching skills, and greater knowledge of cognitive processes that enhance student learning, than today's faculty possesses. This program develops these abilities.

Another objective of this GK-12 project is to improve science learning of students and assist in the professional development of teachers in grades 3-8. These groups are targeted because this is the time when most young people are either turned-on, or turned-off, to science. Too often, science and mathematics are viewed by the students as facts and figures to memorize, with little significance to the world around them. Engineering (the art of applying scientific and mathematical principles, experience and judgment to make things that benefit people) can provide the applications that make science real to the novice learner.

These two complementary objectives are being addressed by an interdisciplinary project that involves graduate students from the five departments in the College of Engineering and Information Technology. Mechanical, chemical, electrical, computer, civil and environmental engineering students work with grades 3-8 science teachers and their students to introduce engineering examples, experiments and inquiry and design problems to stimulate science learning.

The first cohort of Fellows started in August 2001, and includes four Ph.D. students, five M.S. students and two undergraduate seniors in an accelerated BS/MS program. All are U.S. Citizens who are majoring in mechanical, chemical and environmental engineering and have expressed interest in an academic career. Their first semester, the Fellows enrolled in a graduate course from the College of Education, EDTE 701 - Special Topics in Teaching Science. The course is taught by GK-12 project Co-PI and is designed specifically to prepare engineering students to teach, and can be used to fulfill degree requirements for the Fellows. The course includes a 10-hour/week practicum, where the Fellows worked with master teachers in elementary-level Professional Development Schools. In this way the Fellows improved their understanding of teaching and learning, and enhance science education by implementing hands-on activities and design challenges that are aligned with state science standards. During their second semester, each trained and experienced Fellow has moved to a different elementary school - a school that has historically not benefited from a close relationship with the university. All of the schools are located in the urban and suburban areas of Columbia, South Carolina. The following summer, the Fellows organize and present a teacher recertification workshop called "Engineering - The Stuff of Science." In the workshop, Fellows will help teachers who did not have the opportunity to participate directly during the school year. This yearlong program plan will be repeated with middle schools and again with elementary schools in subsequent grant years.

Activities

The graduate Fellows help teachers adopt, adapt and develop state-of-the art learning materials that situate science learning in design problem solving and other experiential learning activities. The Fellows provide content knowledge from their particular sub-disciple of engineering to the appropriate teachers, effectively integrating their teaching and research activities. For example, civil engineers help teachers and students meet the state science standards on earth materials and earth processes. Environmental engineers help with ecology and earth processes. Chemical engineers help with heat and changes in matter, mixtures & solutions and chemistry. Electrical engineers help with sound & light, electricity & magnetism and physical science. Mechanical engineers help with the many state science standards dealing with forces, machines, motion, work and energy. Examples of some of the activities implemented by mechanical engineering graduate students include the following.

Black Boxes – The black box activity was an introduction to models and the engineer's and scientist's use of models to describe what they cannot directly observe. Black boxes were prepared with a variety of shapes inside the box that altered the free space available for a marble to occupy. A marble was sealed into the boxes with the shapes, and each box was marked with an identifying letter. The boxes were given to small groups of students (2 or 3), and the students were challenged to identify what was inside the sealed boxes. After only a few minutes, students were asked for their observations. The class agreed the boxes contained a marble and something that prevented the marble from rolling everywhere within the box. Next, the idea of a model was introduced as a tool to explain something that cannot be directly observed. The students then began the task of drawing the shape of their box's interior. At the end of the class period, all student groups with the same letter on their box met to discuss their findings. The word consensus was introduced, and the idea of scientific collaboration was discussed. The discussion included the importance of writing skills as the primary means of disseminating scientific and engineering information. Groups with like boxes were challenged to agree on their models. Students were then asked to return to their seats, and a representative from the groups presented their initial findings to the class.

The next class period, the boxes were handed-out to the student groups again, and the students were given time to investigate the movement of the marble, again without being able to see the marble or the box interior. The idea of model refinement was introduced, and student groups were given the opportunity to change their drawings of the box interiors. Again, students presented their findings and described the methods they used for developing their models.

Hum-dingers – As a continuation of the model concepts developed during the Black Box investigation, students were presented with a "Hum-Dinger."   This object was covered with a brown paper bag with a single string protruding through the side of the bag. After demonstrating the machine's function, students were allowed to operate the hum-dinger. When the string was pulled, the machine within the bag hummed; when the string was released it dinged. Next, student groups of three or four were given a bag of materials that included batteries, a motor, a bell, several tinker-toy like objects and a base. The class was told that the bags contained all the materials needed to construct the hum-dingers, and they were challenged to create a machine that would operate like the one in the bag. The groups worked for about one hour, then the machines (none of which worked) were disassembled and collected.

The materials were returned to the groups the next class period, and they began constructing their machines. By beginning with only parts, not the machine built previously, the students began generating new ideas. After 1.5 hours, groups began announcing their success. Ultimately, all the groups had working models, and the students were asked to present their designs. To their surprise, none of the hum-dingers were made the same, but they all worked. This was an opportunity to discuss engineering methods and the notion that not all problems have a single correct solution.

Go carts – This activity included the significance of mathematics in engineering design. This activity took place over several science class periods and ended with a four-hour session. First, students were given a bag of materials that included several tinker-toy like objects, rubber bands, paperclips, clothespins, and binder clips. The students were challenged to design and build a go-cart that would be able to travel down a ramp. Many of the student groups found this to be very easy and quickly had a working go-cart. The concept of gravity as a means of propulsion was introduced, and the more complex notion of friction, including the factors that affect frictional force were discussed. This discussion arose mainly from the student questions concerning their go-carts sliding down the ramp instead of rolling.

Next, the groups were to design and construct a go-cart that could move without the use of gravity. Immediately, the students asked for the motors used during the development of the hum-dingers; however, the students were challenged to find something within their bags that could be used as a means of propulsion. After much experimenting, the students found several ways of using the rubber bands to generate enough force to propel the go-carts.

After all the groups had working rubber band propelled go-carts, they were asked, "How would you make your go carts go farther?" After some discussion, the notion of larger diameter wheels was introduced. Along with the concept, the mathematics governing the relationship between wheel diameter and distance traveled was discussed extensively. The students then had to calculate the proper diameter of their wheels to travel a specified distance using a specified number of rubber band windings. After completing and explaining their calculations, the groups made wheels of the needed diameter from cardboard (see Figure 1). The go-carts were modified and the calculations were tested. This was another opportunity to discuss the differences between the ideal, mathematically predictable world, and that in which one cannot easily account for all the engineering losses.

Although much of the terminology was diluted, several advanced topics were introduced, namely, free body diagrams, factor of safety, coefficient of friction, and normal force. Furthermore, the emphasis of the design project was the integration of mathematics and science. Many young students view the subjects as separate entities and were surprised to see math being effectively used during science class.

Figure 1. The go-cart design challenge motivated student learning. One of these students commented "It's good to use math during science so I can predict how far my go-cart will go."

Robot Introduction – As a conclusion to the first half of the academic year, the instructor brought several robotic projects from both the university and his own collection. The robots accompanied a PowerPoint lecture covering the many engineering aspects associated with robotics. The students were enthralled by the information, and many left stating they would be designing and building robots over the holiday break. Robotics is an effective means of introducing students to many engineering concepts, but again, the integration of mathematics, science, and engineering was emphasized with a very tangible and observable result.

Project Assessment Process

The College of Education's Office of Program Evaluation is conducting assessment and evaluation of the GK-12 project. The project assessment plan includes quantitative and qualitative analysis and documentation. Specifically, *documentation* is used to verify the project's conformity to design, i.e., verification that activities or products planned for each objective occurred or resulted as described in the project narrative; *quantitative analysis* is used to evaluate objectives described in numerical terms, such as frequency counts, standardized test scores, or quantifiable changes in behaviors, etc.; and, *qualitative methodology* is used to describe and evaluate data that are not amenable to quantitative analysis and/or are most informative when presented in narrative form.

Subjects of assessment are the Fellows, K-12 teachers, and students. Dependent variables for the assessment include the following: (a) Fellow's perceptions of their skills and understandings; (b) perceptions of teachers; (c) K-12 students' attitudes and understandings related to engineering careers; (d) student achievement in science. Instruments include: (1) Likert type scales to assess Fellow's perceptions of their knowledge and skills related to teaching; (2) Fellow maintained journals, focus group and individual interviews; (3) Focus groups to determine participating teachers' perception of their changed knowledge and ability to use engineering problem solving activities to enhance student understanding of science; (4) Survey instruments which assess K-12 students attitudes toward and understanding of engineering as a career; (5) standardized achievement tests in K-12 science; and (6) longitudinal data such as the Fellows performance on qualifying exams, time-to-degree, number of Fellows who are women and minorities, and job placements of Fellows upon graduation.

Analysis of the most of the data obtained during the 1st placement of the Fellows (Fall 2001) is still underway as of the time of writing this paper. The results of focus groups are discussed in the following section to illustrate how the project is progressing.

Focus Group Methods. Teachers from the five participating schools were recruited beginning in September 2001. Two focus groups were held to accommodate the teacher's schedules. The first had four of the 11 participating teachers. The second focus group had five other participating teachers. These focus groups were conducted in order to determine what activities and environmental situations were affecting participating teachers' knowledge, attitudes, beliefs and behaviors about the program. All focus group participants were Caucasian female teachers at Richland and Lexington County elementary schools. All information collected in each focus group was kept confidential and summarized in such a way that individual responses could not be identified.

Each focus group required about an hour to complete. Prior to the start of the focus group, the purpose of the focus group was explained and each participant agreed to be audiotaped. A trained moderator facilitated each focus group. The focus group participants were asked 10 open-ended questions concerning the success and possible approaches to improve and enhance the teachers' and students' experience of the project. Both focus groups were transcribed verbatim into a word processing system. The information was then coded using Nvivo version 1.2 to identify and define issues and themes. Focus group information included the date and the physical location of the focus group.

Focus Group Results. Each participant was asked to give a brief overview of her experience with the assigned USC fellow. In general each participant said she began with concerns due to not having clear expectations with respect to responsibilities of them or responsibilities of the USC fellow. However, each participant said once the semester was underway, a comfort level developed between the teachers and the USC fellows. Also, the students enjoyed having the USC fellows in the classroom and looked forward to them being there as well as the activities the USC fellows implemented in the classroom.

Participants were asked what each knew about the GK-12 Engineering Fellows program. There were a variety of answers. It was clear that most of the teachers gained understanding of the project through conversation with her assigned USC fellow as the program progressed. About a third of the teachers had some knowledge of the program before the assigned USC fellow arrived in her classroom through contact with either a principal investigator or the principal of the elementary school. More specifically the teachers were prompted as to how knowledgeable each was as to her role in the GK-12 Engineering Science Fellows program. None of the teachers had seen any paperwork regarding the program such as goals and objectives, which had previously been given to either the principal or a lead contact teacher. The teachers expressed not being aware of any specific requirements of them by the program. The teachers expressed some guilt about not knowing if they were helping the USC fellow obtain the goals and objectives set by the program and consequently USC.

Participants were asked how the program helped them apply advanced principles of science to engineering problem solving activities in the classroom. Each teacher described hands-on activities used by the USC fellow that initiated excitement and learning in their students. Many of the teachers expressed that they would not have been able to do hands-on activities if they had not had the help and expertise of the USC fellows. The teachers also were asked for suggestions for improving the GK-12 Engineering Fellows program. All of the teachers said they would like to have a meeting before the fellows begin in their classrooms to discuss lesson plans and possible activities for the semester. Each teacher also wanted some sort of written guidelines as to what is expected of them and what is expected of the USC fellow. The teachers all voiced that the concept of the program was excellent and did, in their opinion, succeed; however, they wanted more structure for themselves and possibly the USC fellows to "fine tune the program."

Focus Group-Motivated Project Improvements. As a result of teacher feedback through the focus groups, the principle investigators wrote guidelines as well as conducted an introductory meeting for the second semester of the GK-12 Engineering Fellows program. Newly recruited teachers were paired with USC fellows and encouraged to talk about planning and meeting times, the school environment, USC fellow schedules and other pertinent information at the beginning of the semester before the fellows reported to their assigned schools. This enabled better placement of fellows in the schools than was achieved when school principals were the primary contact with the university.

Concluding Remarks

Though still relatively young, this GK-12 project has already improved the teaching and communication skills of the participating engineering students, and is having a positive impact on K-12 teachers and students. Continuous improvement of the program is expected based on on-going formative assessment processes.

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