Engineering Students in K-12 Schools

Laura J. Bottomley, Elizabeth A. Parry, Sara Washburn,
Amy Hossain, Rachel Meyer
North Carolina State University

Abstract

There is a wealth of knowledge and information to be shared between elementary, particularly K-5, students and college engineering students. Increasingly, children are deciding on those subjects they like and dislike (and therefore do and don't do) as early as elementary school. Anecdotal evidence suggests that females, in particular, lose interest in math and science in mid-elementary school. An innovative new program in North Carolina's Wake County is attempting to influence the academic choices of the elementary student, particularly young girls and underrepresented minorities. This is the pilot year of an NSF funded program that places college of engineering students as resources at public elementary schools.

By using graduate and undergraduate engineering students as science resources, the children are exposed early to the idea of science, math and/or engineering as a college, and therefore career, choice. The engineering students benefit as well, learning valuable communication skills that will enhance their marketability upon graduation. The ability to explain complex science to children requires confidence and technical knowledge. The ability to impart this knowledge in a useful way is a much sought after skill in the workplace. The school benefits from the early exposure to SMET, and teachers benefit by their participation in workshops and training sessions on incorporating science into daily lessons.

An additional unique aspect of the program lies in its addressing the topic of teaching of science to special needs children. Special needs in our population include ESL (English as a second language), hearing impaired and visually impaired students. Incorporation of these special needs in teaching SMET is a key part of our program.

Benefits to the K-12 schools include curriculum that integrates science, technology, and engineering topics with math, reading, and writing. Benefits to the Fellows include improved communication skills and self-image.

The Program

This paper describes the planning and implementation phases for a NSF sponsored GK-12 Teaching Fellows program. Students from North Carolina State University College of Engineering are placed in elementary schools in Wake County. The activity theme for the program has a primary focus on physics, engineering and math. Curriculum development is done with consideration to various learning styles and to teaching science and math to diverse populations. The particular diverse populations addressed are children who have been identified as "at risk," hearing-impaired students and students for whom English is a second language. An underlying theme of the entire program will be encouragement of underrepresented groups in SMET through role models and particular teaching techniques. This theme will be emphasized in both the recruitment of the Fellows and the teaching of the students. Benefits to the K-12 schools will include curriculum that integrates science, technology and engineering topics with math, reading and writing. Benefits to the Fellows will include improved communication skills and self-image.

The team uses hands-on learning activities to enhance the educational experience of learners in grades K-5 in science, math, engineering and technology subjects. This experience is tuned to students of different learning styles as well. Research has shown that most engineering undergraduates are visual, active learners, and that this reflects the styles of the general population[1]. For this reason, most SMET concepts can be learned best through incorporation of hands-on exercises. This is especially true for hearing impaired students and students for whom English is a second language, for whom verbal explanations may have reduced effectiveness. Although these types of curriculum modules may be the most effective and memorable for students, they also represent the greatest investment of time and resources for teachers. The Fellows augment the teacher's efforts in many different ways: assisting in a teacher-led activity, leading the class in a module developed by the Fellow, or teaming with the teacher to introduce a subject using a dual approach.

A university has resources, such as access to superconductivity demonstration supplies or various bits of machinery, usually not available to elementary schools in North Carolina.

Fellows are recruited through the NCSU College of Engineering Dean's office and via solicitation through various student organizations. Candidates are interviewed by the PI initially, and then meet in small groups with other members of the team. Desirable attributes include an affinity for working with children as well as the ability to learn familiar things in a new way. After all, this program is based upon unique and innovative implementation of SMET. The Fellows selected for participation in this grant activity work with the faculty team and elementary school team to develop modules in physics, math and engineering that will in turn be used in classes at levels K-5. Some examples of topics have been selected as a result of a previous collaborative effort with local elementary schools in Wake County.

The thematic bases for this effort are summarized below:

- integration of science, technology and engineering topics with math, reading and writing

The State of North Carolina has instituted an approach to student achievement based on standardized tests in reading, writing and mathematics[2]. Schools and principals are rated

according to the percentage of students who score at or above grade level on these tests, and teacher bonuses are also tied to student scores. For this reason, curriculum integration has become an ever more pressing need. With the goal of 95% of students at or above grade level by the year 2003, teachers are spending more instructional time teaching "the three Rs" and less on subjects which are now viewed as "nice, but not necessary," such as science.

In order to help teachers find a way to incorporate more science into the instructional day, this project has as an objective the formulation of curricular materials that incorporate science into reading and writing activities and that merge science with mathematics topics.

- encouragement of underrepresented groups in SMET through role models and particular teaching techniques

From experience we have learned the following[3,4]:

- Girls lose interest in science and math at a higher rate than boys do.
- All students begin to lose their interest, if they are going to, between grades 2 and 4.
- A love of learning spills over into all areas of education.

Supplemental SMET instruction is useful and desirable at all levels, K-12, but if the primary focus is on underrepresented groups, they must be hooked early and their interest maintained. This project has produced flexible instructional modules that can be used in the classroom at any of K-5 age groups. For example, a roll of toilet paper, clay models and a soccer field or hallway are used to demonstrate relative size and distance of the planets. This lesson lends itself well to classes studying the Earth (and its place in the system) as well as those studying the solar system as a whole. Other subjects have been presented at a lower grade level (for example dental health at grade 2) and expanded for upper grades (the digestion process). The structure of the North Carolina science curriculum lends itself to this approach, since topics are presented in similar fashion. The same topic may be presented in two or three grades at the elementary level with different instructional objectives and intensity of treatment [5].

In addition, since recruitment of Fellows is heavily focused on women and underrepresented minorities, the Teaching Fellows, as well the female faculty on this project, serve as role models in the classroom. Various teaching techniques that have been shown to be particularly effective for recruitment and retention of minorities and women to SMET fields[6] are incorporated into the teaching techniques employed by the Fellows. These techniques have also been shown to be good pedagogy for all students, not just minorities and women[7,8]. They include creating a cooperative, non-competitive learning environment where all student voices can be heard and using non-judgmental brainstorming techniques, team and group work.

Additional speculation about why certain groups are underrepresented in SMET fields says that the sciences and engineering fail "to show that they are for us and have always been committed to and reasonably successful at increasing human welfare."[9] Such considerations are also incorporated into the types of examples and experiments chosen to illustrate SMET concepts.

- Teaching SMET content to diverse populations, including hearing-impaired students, students for whom English is a second language, and others

Hands-on learning can be particularly effective in cases where other modes of input are reduced. Through the special opportunities that exist at the pilot school and other local schools, Fellows are developing curriculum modules with the special needs of diverse population groups in mind.

- Adaptation of SMET content to different learning styles[10]

Another negative implication for which elementary school teachers may not have time to compensate is the different learning styles presented by various students. A great deal of experience at the university level has given us insight into ways to teach to sequential and global learners, to active and passive learners, and to inductive and deductive learners. One way to address these different styles is to present a single concept in more than one way during the course of a lesson. The Fellows incorporate these alternate presentation styles into teaching and curriculum development.

Implementation

The pilot elementary school working with North Carolina State University is Combs Elementary. This school was chosen for the pilot because the PI already had a presence at the facility. Combs was recently recognized as a National Blue Ribbon School of Excellence by the U. S. Department of Education and as a North Carolina School of Distinction. Combs' student population comprises students from approximately forty difference countries around the world, speaking over fifty different languages. Combs also houses a Hearing-Impaired program. Approximately thirty percent of the student body is eligible for free or reduced priced lunches (a measure used to estimate the numbers of children "at risk" for failure). The population seemed ideal for a pilot test of the GK-12 program. Future schools will be recruited for the program through contact with principals. Selection will be made based on a demonstrated willingness to commit administrative time to implement the program, and a clear desire to participate from the school's staff.

The program was begun by sending attitude surveys to each child, parent and teacher in the school. The children completed a very short survey in class under the guidance of their teachers so that the same survey could be used for pre-reading kindergartners and fifth graders. The children's survey consisted of five multiple-choice questions and a sheet of pictures of people. The children were asked to indicate which of the people were scientists. All of the pictures used were of scientists, but none were high profile in the present day. Some of the scientists were female, some African American, some Hispanic, and some Caucasian. Parent and teacher surveys were anonymous and voluntary.

After the completion of a one-week survey period, an all school science assembly was held. Demonstrations involving physics (motion, electricity, and statics), engineering and chemistry were all presented in a showy fashion. The children were told up front that " not much explanation will be given during the assembly." The goal was to show in a very real way how science can be exciting and to generate questions. This portion of the project was apparently quite a success as students talked about the various parts of the assembly for weeks afterwards. Many teachers used the morning assembly for launching afternoon writing activities.

The next day, a box was placed in the media center labeled as the "Science Answer Box." Children (and teachers) are encouraged to place science questions in the box. The Fellows answer the questions, usually after research, in letters mailed to the children through the school mail service. Once a week a question is selected to be answered live on the video news broadcast of the morning announcements. Children whose questions are answered on the morning news are presented with a Discovery Channel pen. The goal of each of these activities is to raise the profile of science activities and to encourage children and teachers to realize that science is an integral part of daily life, not a specialized and unattainable subject taught in the classroom during a predetermined time.

Fellow-Teacher Contact

The introductory activities listed above were designed to, more or less, set the stage for the main part of the program involving Fellow-teacher interaction. The Fellows at Combs have a goal of fifteen hours per week of teacher contact, but the form that contact may take varies. Initially, the Fellows were connected with particular teachers to observe various grade levels, not necessarily during science. The Fellows also took on students for math tutoring either above or below grade level. The primary goals of this portion of the project were to train the Fellows with regard to grade level work and to working with kids. They observed both experienced and new teachers. Each Fellow is required to keep a journal to document each contact and to record lessons learned and general impressions.

The next step was to have been for teachers to sign up for the Fellows during their available times to come in and help with science lessons or to act as a resource for teacher directed lessons. Although repeated contact with the faculty yielded protestations of good intentions, only two teachers took advantage of the opportunity. The faculty was again queried as to whether they felt the project to be valuable and whether they remained committed. All agreed that they still wanted to participate.

Working with the assistant principal, a schedule for teacher/task was mapped out for each Fellow. This reduced the flexibility of their time (an initial priority), but was deemed much more satisfactory by the Fellows themselves. During a given day, a particular Fellow may go to three or more classrooms to help with math, computers or science. The Fellow may present the lesson or assist the teacher. Some of the scheduled time is with teachers only for the Fellows to act as resources, and some of the time is set aside for research and preparation time for the Fellows. Not all teachers have a scheduled time, but the schedule is reevaluated each semester, and some teachers may only participate for half a year at a time.

This particular arrangement has proven to work well. During the second semester of the program, all of the teachers in the school (with the exception of one who has a time conflict) are participating in the program. We believe that the reason this arrangement works best is that Combs has a large proportion of experienced teachers who, for various reasons, are more reluctant to be perceived as “asking for help.” To illustrate with a few specific examples:

- In a fourth grade classroom, the teacher introduced the topic of “states of matter” with a brief lecture. The fellows followed up with an activity that required all of the students to leave their desks and become “molecules.” The teacher then tied the activity back to her introduction to conclude the session.
- In a multi-grade hearing-impaired classroom, the fellows provide much of the science instruction that the students receive. The teachers maintain order and interpret the lesson into American Sign Language. The teachers and fellows work together to maintain a list of signs needed to instruct that particular lesson with the goal of suggesting a comprehensive list of science terms to be taught in the schools system-wide.
- In a first grade classroom the fellows fill the role of “visiting scientist,” bringing an experiment for the class to perform that goes along with the science lesson that they will receive from their teacher at another time during the week.
- In all of the fifth grade classrooms, the fellows are working to complete a complex project that integrates the science, math, social studies and technology lessons that the students are receiving from their teachers. Two of these projects have included designing a playground and making a detailed map of the school.
- In an English as a Second Language (ESL) classroom, a fellow provided a hands-on lesson to repeat the lecture that the students had already received in the regular classroom to reinforce and further illustrate weather concepts.

An additional element that will be added in the spring semester is teacher workshops. One currently in development concerns ways to introduce various science topics with "quick and dirty" hands-on activities. Another concerns using the World Wide Web for curriculum integration.

Curricular Content

The Fellows have developed curriculum on a variety of SMET topics and are working on others. Some of the topics show evidence of the kind of curriculum integration that is a goal of the overall project. For example, the Fellows developed a class on pumpkins to conduct in conjunction with literature, writing and art activities that have been done in the classrooms for many years. These activities have included reading pumpkin stories every day during the unit, painting pictures and gluing cut-outs of pumpkins, etc. The class was used with first, second and third graders in appropriate form. The children were first asked to brainstorm questions about pumpkins that were classified into various groupings as a teacher-led activity. The Fellows then brought in a collection of different sizes and colors of pumpkins. The children rotated through stations where the pumpkins were weighed and measured. Using age appropriate skills, the data were graphed. First graders made bar graphs of the various pumpkins' weights, circumferences and heights. Third graders graphed weight versus height and/or circumference. During the lesson, scientific reasoning and the scientific method are discussed. The lesson concludes with an example of an experiment using the scientific method; the pumpkins are placed in a large tub of water to see which will float after the class votes on their predictions. The questions that the class originally brainstormed are answered during the course of the class or at the end, as appropriate.

After the conclusion of the class, students in all grades did a writing activity to describe pumpkins and/or write an imaginative narrative about a magic pumpkin and another activity using affinity diagrams to classify pumpkin traits. Both of these follow-up activities were obviously influenced and informed by the science lessons, as evidenced by examination of the students' work.

Other topics have included working with place value in math, simple machines, solutions and mixtures, apples (similar to the pumpkin class described above with the addition of predicting the length of an apple peel involving measuring skills and two-digit addition), the solar system, energy, and others. New topics are being invented to fit the needs of the teachers each week. One longer-term project includes investigating robots. Many of the topics were selected by careful observation of the classes and by observing the behavior of the children in the library! The classroom teachers don't always seem to know when a topic is appropriate for curriculum integration, so these "undercover" activities allow the Fellows and NC State faculty to suggest ideas.

Assessment

The goals of the project are specific, but not necessarily completely measurable. Still, a set of assessment "rubrics" has been selected for evaluation at the end of each school year. One rubric used in assessing the program will be the likelihood of the various activities to have long-term impact on students, teachers or both. This is somewhat vague, but is felt to be quite important. If the fellows are left in charge of the science lesson in a particular classroom on a regular basis with the teacher "checking out," either literally or figuratively, that interaction will be judged to have been ineffective. The teacher will have gained nothing from the experience.

The student, teacher and parent surveys will be repeated at the end of the year to determine whether attitudes toward science have been affected in any way. Some of the questions on the parent survey ask how frequently children ask about science at home, so this will also be compared at the beginning and end of the year. By the same token, the teacher surveys revealed that some teachers have a fear of teaching science. Hopefully, these attitudes will have also changed, and they will feel better equipped for science in the classroom.

Under the hypothesis that the various targeted groups may have been encouraged and helped in their overall learning, school test scores will be compared with those of previous years. Individual science grades will also be assessed for the targeted groups. The number of students participating in the school science fair will be compared from year to year as well.

Other quantifiable data that will be noted includes the number of students submitting questions to the "science answer box," and the number of questions submitted over time. This should reflect whether an ongoing interest in science subjects exists beyond the classroom.

The project will be rigorously evaluated by both Fellows and elementary school staff and examined for ways to improve and/or change for the next year. Each teacher will be asked to assess her/his fellow interactions and the program overall.

All of the project themes, as stated in the first section of this document, will be evaluated separately using the above measures to determine whether any or all of the goals are being adequately addressed. In addition, after the pilot year is complete, we will reassess *how* we assess to project to determine if additional measures are possible and desirable.

Although a long-term longitudinal impact study is beyond the scope of this project, the PIs are hoping to extend the project with additional resources to track a population of students through elementary, middle and high school. Grades, interest (as indicated by survey), and courses taken in high school are some of the measures proposed to be tracked by gender and ethnicity.

An unexpected benefit to the program has resulted in incorporation of some of the attitude and problem-solving techniques used by Combs elementary teachers into the freshman engineering course at NC State. Combs is using the Baldrige[11] quality tools in K-5 education. The PI is translating and applying them to freshman engineering.

Conclusions

This project aims to address four main themes to enhance the way science is taught at the K-12 level in Wake County, North Carolina:

- curriculum integration
- encouragement of underrepresented groups in SMET
- teaching SMET to diverse populations
- adaptation of SMET content to diverse learning styles

This is accomplished by sending graduate and advanced undergraduate engineering students into public schools to work in partnership with teachers and staff there. The partnerships have not been easy to define and implement, but success has been achieved. Communication is open and flowing with the pilot school, and exchanges have taken place in both directions of the pipeline.

References

[1] R.M. Felder, "Reaching the Second Tier: Learning and Teaching Styles in College Science Education," J. College Science Teaching, 23(5), 286-290 (1993).

[2] http://www.dpi.state.nc.us/student_promotion/draft_standards.html

[3] *Educational Researcher*, Volume 27, Number 5, June-July 1998.

[4] Piller, Charles, "Gender Gap Driving Women out of Careers in Computing," *Houston Chronicle*, August 30, 1998.

[5] http://www.dpi.state.nc.us/curriculum/

[6] R.M. Felder, "A Longitudinal Study of Engineering Student Performance and Retention. IV. Instructional Methods and Student Responses to Them," J. Engr. Education, 84(4), 361--367 (1995).

[7] Rosser, Sue, ed., Teaching the Majority, Teachers College Press, 1995.

[8] Rosser, Sue, Female Friendly Science, Teachers College Press, 1991.

[9] Mayberry, Maralee and Margaret N. Rees, “Feminist Pedagogy, Interdisciplinary Praxis, and Science Education,” NWSA Journal, July 1994.

[10] R.M. Felder and L.K. Silverman, "Learning and Teaching Styles in Engineering Education," Engineering Education, 78(7), 674 (1988).

[11] Arcaro, Jerome S., The Baldrige Award for Education: How to Measure and Document Quality Improvement, CRC Press, 1995.

LAURA J. BOTTOMLEY is the Coordinator of the Women in Engineering Program and an Adjunct Assistant Professor of Electrical and Computer Engineering at North Carolina State University. She received her BSEE and MSEE degrees from Virginia Tech and her Ph. D. from North Carolina State University. She has worked at AT&T Bell Laboratories and Duke University.

ELIZABETH A. PARRY received her BS degree in Engineering Management from the University of Missouri, Rolla. She worked at IBM before leaving to pursue an interest in teaching science to children. She is co-owner of Science Surround, a science education business for children. Ms. Parry is presently consulting with North Carolina State University on outreach.

SARA WASHBURN is a senior in electrical and computer engineering at NC State University. She is schedule to graduate in May 2000.

AMY HOSSAIN is a graduate student in industrial engineering at NC State University. She is pursuing a masters degree.

RACHEL MEYER is a senior in textile management at NC State University. She is scheduled to graduate in May and plans to apply for a lateral entry teaching position in a public school.