Infusing Engineering into Public Schools

By: E. Rushton, M. Cyr, B. Gravel, L. Prouty
Tufts University, Center for Engineering Education Outreach

Abstract

In 1998, the Tufts University Center for Engineering Educational Outreach (CEEO) was the recipient of a grant from the National Science Foundation (NSF) to provide fellowships placing graduate engineering and computer science students with teachers in Massachusetts' primary and secondary public schools. The primary intent of Tufts' outreach program centered on introducing graduate-level engineering students as resources to assist classroom teachers in implementing activity and constructivist based engineering curricula. Massachusetts is the first state in the nation to require engineering education at all levels in public schools, through the adoption of Science and Technology/Engineering frameworks; as a result, the need to develop specific curricula in support of these new frameworks is particularly important. This NSF grant facilitated direct graduate student support of teachers recently charged with implementing novel educational frameworks involving engineering, as well as indirect undergraduate student support.

Tufts CEEO GK-12 Outreach Project

The Tufts University GK-12 project is a three-year project focused on pairing graduate-level engineering and computer science students with classroom teachers. The CEEO had 6 graduate fellows in the first year of the project, and currently has 8 graduate fellows working in the classroom. Selection for program participation involves a yearly application process subsequent or concomitant to admission to the School of Engineering. Students complete an application with essay and submit it to the Center for Engineering Educational Outreach for consideration. Top candidates are then identified from the applicant pool and offered individual interviews with the grant's principal investigator. Throughout the application process, assessment is made of individual experience, understanding of Center's mission and vision for the development of primary and secondary engineering education, and ability to work effectively with teachers and children involved with program.

Within the graduate academic program, GK-12 graduate fellowships take the place of a traditional research assistant (RA) or teaching assistant (TA) position at the School of Engineering providing tuition and stipend. Fellows spend 20 hours per week on the project, with 16 hours (2 full school days) per week spent in the classroom of their partnering teacher. The remainder of the time allotted by fellows is spent taking part in seminars relating appropriate educational pedagogy, discussing classroom strategies for learning, and interacting with undergraduates working to support curricula ideas. Currently, graduate fellows formally partner with 10 technology education and science teachers, as well as 3 math teachers in grades 3 – 9. Each year, fellows interact formally with approximately 470 students in technology education and science classrooms and 250 students in math classrooms. Informal support takes place with similar numbers of social studies classes in crossover activities, although no social studies classroom teachers are formal partnering teachers. The project runs from June 1 to May 31 of the following year, allowing consistent contact between graduate fellows, classroom teachers, and program administration. The program will continue to place and support fellows and teachers from Fall 2000 until Spring 2003.

Classroom teachers involved in this project represent both a district-selected and a self-selected subset of technology education, science, and math teachers within the Nashoba Regional School District, the program's partner district. Teachers can become involved either as a result of individual expressed interest in the program or as a product of administrative identification of increased need for engineering education. Relationships between the teacher and the fellow is dependent on several factors, among which are teacher experience, teacher comfort level with the material, graduate fellow comfort with instructing a class, and teacher-fellow interaction.

Tufts CEEO Approach to Project Development

Though the outreach project continues to undergo modifications throughout its implementation period, the core philosophies remain consistent. The Tufts CEEO approach focuses on integrating engineering and problem solving into established and modified classroom curricula in science, mathematics, technology/engineering, and social studies through the use of problem/project based units and inquiry/experience based learning. These projects have been used both to introduce and to reinforce concepts in engineering (particularly Massachusetts Science and Technology/Engineering framework content) within science, mathematics, and social studies classes. Importantly, the CEEO has used input from students, teachers, and administrators to help determine how to introduce engineering at various grade and ability levels effectively.

Tufts CEEO Approach to Partner District Involvement

In Massachusetts, the recently adopted new educational frameworks include engineering as one component of mandatory education for all public school students. Therefore, the classroom inclusion of engineering is greatly facilitated and the relevance of engineering content support offered by fellows readily appreciated the school community and administration. However, to benefit project success, the school district administration should be evaluated both in terms of formal and personal levels of understanding of relevant project goals as well as overall involvement or support of the project. While some administrators chose to be involved in all communications between the university and partner teachers, others are happy to be contacted only to troubleshoot prospective issues, or simply to be kept updated on project status. Though agreement on the level of involvement between the outreach group and district administration is important, the consistency of administrative involvement is crucial to CEEO project success.

Tufts University has an extensive history of working with the Nashoba Regional School District as demonstrated by a 14-year collaboration between the two institutions. However, even given long-term relationship, many issues required examination before implementation of this new cooperative program. The issue most central to initiating successful school outreach work was that the implemented program must work within the existing academic structure. Though innovative programs may have extensive proposed merits and represent insightful advances in education, if proposals do not mesh with the state and/or district curricula, program implementation will (rightfully) be challenging, if not impossible. Cooperation via an outreach focus group, for example, with a school district at the point of initial program development and grant proposal can be an integral part of the process. Initially, curricula must be examined and prospective areas for engineering content addition must be identified initially.

Clear communication between district administrators, teachers, graduate students, and outreach project representatives is crucial in the process of successful outreach development. Clearly, problems most often develop where the communication ties are weak or nonexistent. It should never be assumed that project information will naturally disseminate to reach all parties involved; direct communication is the only method to ensure smooth operation.

Tufts CEEO Approach to Integration within Primary and Secondary School Curricula

In the case of the CEEO GK-12 project, graduate students are placed in a classroom (or group of classrooms) for entire school years, allowing ample time to investigate class curricula and experiment with implementing activities in different ways and in different contexts. While this ongoing placement is not a component of many other successful outreach activities, aligning projects with traditional curricula remains a crucial goal. This association allows outreach establish relevance with ongoing classroom learning—and real educational value—rather than facilitating a single "showcase" type of demonstration, which has limited educational application for teachers and students.

An appropriate engineering activity integrated into regular school curriculum can have two major results: first, teachers become able to see how engineering can compliment and tie together traditional classroom content. When shown how engineering and computer science content can fit into existing lesson plans, teachers become more ready to use the this material, which enriches students' educational experiences. The second major result of integrating engineering activities is that students are shown how engineering relates theoretical science, mathematics, social studies, and language arts material being taught. Quite simply, engineering often provides relevance to students, a factor often lost in traditional curriculum. This loss often leaves children, if not teachers, without rationale for learning, retaining, or valuing the material. Practical, activity and constructivist based learning, used to reinforce or present relevance of important content and effectively influence increased information retention through application of learning, benefits student learning. Engineering can also provide an opportunity to encourage students (particularly students underrepresented in engineering fields) to pursue further education in math or science to be able to appreciate fully lessons given.

Tufts CEEO Approach to Project Funding

Definition and reasonable resolution of prospective financial issues prior to project implementation is important. If the partner school district agrees to provide financial or material support, a clear, itemized budget outline expected to carry the program to completion should be developed. It is important to ensure that all financial support or material (particularly in the case of capital expenditures or basic program infrastructure items) is purchased and available for use prior to project implementation. Since one goal of the CEEO program is to increase teachers engagement and belief in the integration of engineering into curricula, care should be taken to avoid prospective missteps due to lack of financial or material support.

Tufts CEEO Approach to Partner Teacher Project Involvement

A crucial part of the CEEO philosophy is to limit additional work created by involvement with the project for individual partner teachers. While this is one area that is potentially easy to overlook, easier implementation in a given classroom of engineering activities results in more successful class activities for both teachers and students. If partner teachers rarely have time to make copies of desired projects, activities requiring handouts should present an appropriate number and quality of copies. If activity resources like books, computer programs, etc. would be beneficial; the materials should be included in supplies collected by the outreach program. It has been the experience of the CEEO that supplying all necessary instructions for both teachers and students will increase likelihood of positive experiences with implementing the activity. A greater proportion of successful activities will benefit teacher investment in integrating engineering content, leading teachers to make engineering activities permanent additions to curricula. While this is in no way meant to imply that teachers are not willing or able to assist in developing activities (and, in fact, many wish to do this), it is important to remember that the outreach model should not inherently involve these expectations, in order to increase program success. At times teachers may offer assistance as a measure of goodwill toward the program or individual fellow and may be soon overburdened with additional work that may cause them to resent the project or outside involvement. Careful consideration of partner teachers' inherent extra project demands must be made when initiating a new project involving the introduction of teacher non-certified engineering content assistants to their classrooms. Balancing demands and rewards for partner teachers is implicit in project success.

The level of partner teacher and graduate fellow involvement, both in terms of frequency and duration, should be determined prior to project implementation. Partner teacher and project expectations should define whether fellows would work with the teacher on a daily or weekly basis, and the duration of this work with a given class. If activities are fairly focused in nature, it may be appropriate for a fellow to work with one teacher during one unit; if broader in scope, throughout the school year. Tufts' GK-12 fellows work with teachers twice a week for the school year to allow significant contribution of engineering and computer science activities without compromising the role of traditional or non-project curricula. Additionally, coordination of daily activities might cause partner teachers to become overwhelmed, given other content demands within their educational goals. It is important, however, not to limit these outreach opportunities (for instance, if fellows were present in the classroom one day each week) inappropriately, as this greatly limits opportunity for development of continuity with students and seamless integration between engineering and more traditional content. The integration provided by having fellows in classes two days per week has proven to be a valuable part of CEEO outreach.

Tufts CEEO Approach to Partner Teacher – Fellow Interaction

A major component contributing to the CEEO outreach project's success has been the maintenance of a positive relationship between partner educators and fellows. While clearly each relationship differs, care in pairing fellows with cooperating teachers must be taken to maximize opportunities for success. Basics such as general communication style and personality types must be considered in matching teachers and fellows; these considerations remain second only to appropriately matching individuals based on classroom needs and content knowledge

Any successful outreach program relies in great part upon effective communication between partner teacher and fellow. A logical starting point in this relationship is the definition and establishment of joint goals for the project in the classroom. It is important that both teacher and fellow understand the outcomes expected by the project and how students' educational experiences can be enhanced by integration of engineering and computer science activities within traditional curricula. Developing this common sense of purpose creates an excellent starting point for positive interaction and involvement in outreach activities on both the part of educators and fellows. Creating this unified sense of purpose involves developing a meaningful explanation of the engineering's relevance to education and society at any level. To an engineer or engineering graduate student, the justifications for this need appear obvious, but to the 2nd grade teacher certified and trained in education, the importance of engineering in the elementary level classroom might not be as readily defined. CEEO experience has shown that breaking down "engineering"—and engineering processes—into less intimidating descriptive words like "design" or "problem solving" helps to clarify the importance of their presence in primary and secondary education. Introducing someone with no technological training to a simple design project (e.g. a Lego design project) while utilizing the engineering design process begins to show the relevance of engineering as a problem solving method. Breaking the concept of design down further into brainstorming, evaluation, testing, and re-designing take away the anxiety associated with "engineering" something. Another crucial step in exposing the merits of engineering at every level of education is establishing tangible connections between engineering principles and real world examples. For example, posing a project the following way can highlight commonalities between engineering and real world problem solving.

A team of scientists is on a small river island downstream from a dam that was just removed. The island is quickly eroding due to the greatly increased water flow that once was blocked by the dam. In a matter of days, the island will erode to the point that it will not be safe for the scientists to inhabit. The scientists have valuable data and equipment on the island that is too heavy for their boats to transport to the mainland. Design a method for transporting the scientists, their important research, and their equipment to safety.

This could be viewed as a very overwhelming project given no parameters, equipment lists, constraints, or solution methodologies. However, if the project is assessed using an iterative engineering design process: gathering research and brainstorming solutions, evaluating the ideas, selecting materials, building a prototype, testing the design, and redesigning, the problem becomes much more manageable. Establishing an understanding of engineering as a problem-solving tool with a generalized, methodology often brings individuals without professional technical education to greater understanding of the importance and inherent, subtle presence of engineering in society. Obviously, the ability to convince a teacher of the importance of engineering will initially vary based on the teacher's educational background, but understanding the philosophical basis for the program is imperative in achieving success.

With an understanding of the relevance of engineering in primary and secondary education and a common set of defined goals for the outreach program, the partner educator/fellow relationship has an excellent platform from which to further mutually beneficial application of engineering activities in existing K-12 curriculum. In order to maintain these common goals and a common vision, healthy communication—a broad term deserving further definition—between teachers and fellows is essential and cannot be overemphasized.

Since the most tangible goal of the CEEO GK-12 outreach is placement of engineering and computer science content resource for the teacher in the specified academic area, it is crucial that communication remain open and peer-based. This style of communication supports partner teachers in feeling comfortable asking questions and requesting explanations of the fellow so that content is never comprised in the classroom. It is incredibly important to ensure that fellows provide appropriate content direction without insulting partner educators. CEEO experience has demonstrated that if partner teachers feel threatened intellectually, particularly in the presence of students or administrators, they will begin to dismiss the project goals. This line between instruction and insult often seems to be a narrow and moving target, in many respects, but can be widened with positive and healthy communication. Positive reinforcement and compromise are key components of healthy communication. The fellow must identify, (out of necessity) early in the year, project boundaries with relationship to particular components of individual teaching style and classroom organization. The fellow may not agree with methods used by the teacher, but judgment in terms of where and how to be involved in content direction with the partner teacher becomes central. This is not a teachable skill, but one that must be developed through classroom experience with regard to individual partner educators. It is important, however, that content should not be compromised as a result of the communication process. Project success demands that fellow vigilantly ensure that inaccurate or imprecise scientific and engineering principles are not incorporated into classroom activities, while fellows must act with tact and diplomacy to safeguard collegial relationships, the cost should never be so high as promulgating scientific or engineering falsehood.

The CEEO outreach project has identified that curricula development time for teachers and fellows is an important facet in the design of outreach programs. This development time can take several forms: during the summer, scheduled development of curricular units with teachers can be effective since curricula often are not finalized. Also, this may allow both deeper and broader curriculum exploration, allowing for modifications to existing curricula as well as the creation of entirely new or innovative work. Effective communication in the educator and fellow partnership also has an essential role here in identifying developmentally and educationally appropriate curricula, since at this point the fellow may have only limited experience or understanding of issues relevant to classroom teachers. During the school year, work can also be done to integrate engineering into classroom curriculum, though this task takes additional planning on the part of the teacher, since necessary or appropriate content must be identified for a given point during the term. Before the lesson is presented, the graduate fellow compiles topics for investigation with the class and presents this material to the teacher who is able to review and modify material, selecting the most appropriate topics. This process does, however, take time; making sure sufficient time exists to bring initial content ideas to fruition can be challenging, particularly in cases where fellows work with more than one partner teacher. Multiple teachers may utilize different syllabi: given this, it may be difficult to effectively create and disseminate engineering projects in a timely manner The CEEO has found that it is much more successful to work around a single curriculum and to develop sample problems for use by other teachers in the same grade during subsequent terms. Since many school districts have a consistent curriculum for each grade level, though content scheduling may differ between teachers, appropriate and usable material remains constant.

Tufts CEEO Outreach Conclusions

The CEEO K-12 outreach project is dynamic and will remain so in the upcoming year. Project strengths previously identified, such as developing strong partner teacher and fellow relationships through communication to best achieve project goals attempt to ensure that this type of outreach activity remains relevant and best serves engineering and computer science primary and secondary education in a changing world of technology. The lessons learned by the Tufts University's Center for Engineering Educational Outreach GK-12 project in Massachusetts, a state with Science and Technology/Engineering standards for all public school students are certainly transferable beyond these boundaries. CEEO experience can be utilized to simulate discussion in development and planning of future engineering outreach activities involving primary and secondary educators interested in infusing traditional curricula with engineering to expand students' educational experiences.

ERIK RUSHTON
Erik Rushton is the Assistant Director of the Center for Engineering Educational Outreach at Tufts University. He has been involved in outreach activities for the past 2 years. He is a member of the Technology/Engineering Advisory Council to the Massachusetts Board of Education.

MARTHA CYR
Martha Cyr is the Director for the Center for Engineering Educational Outreach at Tufts University. She has been involved in outreach activities for the past 5 years and was intimately involved in the creation of the new engineering frameworks for the State of Massachusetts.

BRIAN GRAVEL
Brian Gravel is a Masters Candidate in Mechanical Engineering at Tufts University. He received his BS in Mechanical Engineering from Tufts University as well. He is a first-year NSF GK-12 fellow at the Center for Engineering Educational Outreach working with a 9th grade Science and Engineering class.

LACEY PROUTY
Lacey Prouty is a National Science Foundation GK-12 fellow at the Center for Engineering Educational Outreach at Tufts University. She has worked with middle school technology education students and sixth grade science students since 2000. She is a Master's Candidate in Environmental Health Engineering at Tufts School of Engineering and scheduled to complete her degree in 2002.