Designing an Outreach Project that Trains Both Future Faculty and Future Engineers

Suzanne A. Olds[1], David E. Kanter[1,2], Amanda Knudson[3], Shruti B. Mehta[1]

[1]Biomedical Engineering Department/ [2]School of Education and Social Policy/[1]Biology Department
Northwestern University, Evanston, IL

I. Background

Recognizing that there are more engineering jobs than there are future engineers in the educational pipeline, many universities have developed programs to attack this problem at its roots - in elementary and middle schools. Several different approaches to K-12 engineering outreach have been employed to get students interested in the field of engineering, anticipating that this interest may impact later career choices. Some such outreach programs focus on educating K-12 teachers about engineering so they may pass the knowledge on to their students, while others focus on university engineering faculty directly interacting with the students whom they hope to affect. When institutions of higher education devise K-12 outreach programs, the institution itself must consider many factors; time commitment required of developers, funds available, effectiveness of the program, and program sustainability are those that receive the most attention. The outreach model we have developed has minimized the time commitment of faculty developers and the funds required to sustain such a project, as we rely extensively on undergraduate and graduate student volunteers to develop and implement the project. In addition, this model has created some benefits not addressed by more traditional K-12 engineering outreach models. In this paper, we will describe our engineering outreach model and focus on the three major advantages of this model as implemented through the Biomedical Engineering Department: 1) benefits gained by undergraduate and graduate engineering students who are involved in the development and/or implementation of the outreach module, 2) the enhanced sense of community developed within the Biomedical Engineering department, and 3) long-term sustainability of the outreach program.

II. Project Description

The engineering outreach programs that are most frequently cited as good models of K-12 engineering outreach efforts are those developed by centers dedicated to outreach (ex: the Integrated Teaching and Learning Laboratory at the University of Colorado and the Center for

Initiatives in Pre-College Education at Rensselear Polytechnic Institute). These centers are usually staffed by faculty from engineering and education departments. Unfortunately, maintaining the funding to keep a staff of full-time faculty devoted to integrating engineering and primary school education is a daunting task at most universities. At universities where such centers do not exist, outreach efforts often stem from individual departmental initiatives. The main challenges of departmentally-based programs are 1) lack of time and reward for engineering faculty to contribute to such activities and 2) lack of knowledge of the engineering faculty about how students learn and activities that would engage pre-college students. In the outreach program initiated by the Biomedical Engineering department at Northwestern University, we are addressing both of these issues.

Like many engineering outreach projects, a key goal of this project is to encourage middle school students to develop and/or increase their interest in math, science, and engineering through a real-world engineering problem. In this paper, however, we focus on another goal of the project – to increase students' understanding of the teaching and learning process. Northwestern University is part of the NSF-sponsored Engineering Research Center in Bioengineering Educational Technologies. Engineering faculty in this Center are primarily involved in the design of instructional modules for undergraduate programs. These faculty have greatly benefited from the rich interactions between learning scientists and other faculty interested in improving engineering education. Through these collaborations, engineering faculty have increased their understanding about how people (including themselves) learn and about designing instructional approaches to improve the learning environment. We expected that by providing an opportunity for our undergraduate and graduate students to engage in the same type of collaborative design process for K-12 education, we could achieve the same side effect – improved understanding of teaching and learning.

The key to the project's success is the energy and ingenuity of a group of undergraduate and graduate biomedical engineering students combined with supervision and guidance by one faculty member in the Biomedical Engineering Department and one faculty member in the School of Education. By getting the engineering students actively involved in the collaborative design process, they learn the intent of the instructional approach. They are then able to pass along this knowledge to newcomers to the project, keeping faculty involvement to a minimum.

In the development of this project, students worked with middle school teachers to develop a challenge-based module that addresses one or more of the State of Illinois science goals. One or both of the supervising faculty members also attended these meetings to participate in the discussions and offer guidance when needed. When additional content knowledge was required, the students consulted outside resources, including departmental faculty who often pointed them to other resources such as useful textbooks, graduate students in the field, and industry connections. When implementing the 8-12 period module in the classroom, students take on several roles – discussing homework, guiding the class in the day's activities, managing the structure and timeline of the class, and continually observing the students at work – making notes about time on task, nature of their questions, and conversations they have with peers. Based on their observations and their analysis of student homework and surveys, they continue to iteratively improve the module.

The module that the engineering students are developing challenges teams of middle school students to design, build, and test an artificial limb to accomplish a task requiring either fine motor control or strength. Also introduced into the module, under the suggestion of Chicago Pubic School teachers and the Center for International Rehabilitation, is a social science/humanities component. The artificial limbs need to serve specific people who have lost their limbs as a result of landmines or other war crimes. The middle school students engage in this challenge after reading a story about a boy who lost his leg by stepping on a landmine while playing soccer. The teams are provided with workbooks to guide them through the design process and materials to build the below-elbow prosthesis. The materials provided are limited to those likely to be found in the target country. The engineering students serve as teachers for the duration of the module, which can vary from 8-12 class periods. More information about the module can be found at: http://www.cirnetwork.org/education/cps/index.jsp

III. **Benefits Gained by Student Developers**

Another primary goal of this project is to increase university students' understanding of teaching and learning. Preliminary analysis of a student survey with some open-ended response sections indicates that we have accomplished our objective and have benefited students in ways not originally anticipated. When asked to comment on how they have benefited from the project, the engineering students indicated that they have had to reflect upon their own learning process in order to devise this teaching unit in their specific field of interest:
"*There is great satisfaction in knowing that you aided in the educational development of a young students. You also develop yourself in the process. The on-going development of this project not only allows us to teach kids about the design process but it also allows us to improve the design process and learn it in a way that can be applied to BME and our other projects.*"
Many of the engineering students have found that in order to devise the lesson plan, they needed to dissect the engineering concepts that they have learned and analyze them individually rather than as a whole. This has helped them reflect on and apply concepts previously learned in the classroom.

The majority of students also indicated that involvement in this project has helped them gain and improve their skills in the areas of leadership, management and communication. In order to create a complete lesson plan and the design activities within that plan, it is necessary for the team members to voice their opinions and communicate effectively not only amongst themselves but with educators and their target audience, the middle school students. Throughout the implementation stage, the students take turns teaching the classes, assisting the middle school students, and managing the structure and timelines of daily classroom activities. Graduate students aspiring to be professors and students interested in a future of teaching find the module to be a valuable tool in preparing them for the classroom environment. Those not planning to pursue careers in teaching also find these leadership and communication skills valuable for future endeavors.

IV. **Formation of a Community among Students and Faculty**

Undergraduate and graduate students have reported that a benefit of their involvement in this project is the more extensive interactions that they have developed with peers and faculty. Since the students involved in this project include freshmen, doctoral candidates, and all levels in between, this project provided an opportunity for the students to establish relationships with their peers outside of the classroom as well as with students that they would not interact with under normal circumstances. The project served as an outlet for the students to get to know one another in a different setting and for students to share advice with one another about classes and career paths:
"*I enjoyed working with students from different grade levels (freshmen through graduate students). I was able to get advice about my classes and career goals as well as give some advice. It was nice to further my friendship with people in my classes, especially when it came time to do group projects and work together*."

The engineering students were also able to interact with faculty outside of the classroom or laboratory setting. Some of the students involved in the project presented the module to faculty members at a departmental meeting. As a result, students made connections with faculty that did not previously exist, enabling the students to approach the faculty more easily about other opportunities within the department. Faculty members also learned more about their students' interests outside of the classroom. The engineering students were also able to discover a realm outside of their department as a result of their interactions with the faculty in the School of Education at Northwestern University.

The members involved in the development of the module formed a close-knit learning community because they shared the same goals and interests. This relationship was extended outside of the subject of the project and into the engineering department, resulting in a more cohesive departmental environment.

V. **Long-Term Sustainability**

The outreach project was initiated in September 2001, and it incorporates several elements that indicate that it will be sustainable for several years to come: 1) enthusiastic project developers and implementers, 2) low faculty time commitment, 3) low cost, 4) enthusiasm of module recipients and implementing teachers, and 5) indicators of effectively increasing student's enthusiasm for engineering and understanding of design principles.

A group of about 25 students has eagerly volunteered their time for this project. They are motivated by the desire to do something positive for the community, to apply the engineering knowledge they have gained in the classroom, and to expose students to engineering at an early age. In the early stages of this project, only a handful of students were involved in the project, but the number of students involved has steadily increased as students have spread the word to their peers. Most students remain involved in this project throughout their years at Northwestern, maintaining project continuity from year to year and minimizing faculty involvement.

Since this module was developed with input from middle school teachers and faculty from the school of education, the motivating challenge is one that actively engages the target students.

Many parents have remarked to the middle school teachers that their children and excited about the project and are motivated to share their new-found knowledge outside of the classroom. Prior to instituting the bioengineering outreach module, most of the middle school students were unaware of engineering as a career and the impacts that engineers have on the world. However, after the completion of the project, it was apparent through homework assignments and pre- and post-survey survey responses that their eyes and minds had been opened to math, science and engineering. In addition, the students showed an understanding of the design process, an aspect unfamiliar to them prior to the module.

VI. **Future Directions**

At Northwestern, we bring this module to one Chicago Public School classroom each academic quarter (3 classrooms total per academic year). However, we realize that for this project to have a broader impact, it will need to be extended to more than three schools per year. We are in the process of developing a teacher manual so that it can be implemented by middle school teachers independently. Undergraduate and graduate students will be able to respond to any questions they might have about the implementation of the module or content contained within it. We are actively trying to get student groups at other VaNTH institutions to adopt this project and bring to their local school districts in a similar manner.

ACKNOWLEDGMENT

This work is supported by the National Science Foundation EEC-9876363

BIBLIOGRAPHIC INFORMATION

SUZANNE A. OLDS is Assistant Chair of the Biomedical Engineering Department at Northwestern University and is engaged in the VaNTH Center for Bioengineering Educational Technologies. Prior to joining the faculty at Northwestern, Suzanne was a process engineer for Texas Instruments in both the US and Thailand.

DAVID E. KANTER is a Research Assistant Professor in the School of Education and Social Policy at Northwestern University. After getting his PhD in biomedical engineering from Johns Hopkins University, he worked with xx on the "Learning By Design Project" at Georgia Institute of Technology. David's K-12 outreach work is extensive; he currently leads two other outreach projects.

AMANDA KNUDSON is a senior biology student at Northwestern University. She has been active in this K-12 outreach project since its inception. Following graduation from Northwestern, Amanda plans to attend graduate school in teacher education in order to secure a position as a high school biology teacher.

SHRUTI B. MEHTA is a senior biomedical engineering student at Northwestern University who has been engaged in this K-12 outreach project since its inception. She has served as the overall manager of the project for several quarters and has actively recruited new students. She plans to work in industry after she graduates.