

## Developing a Standards-based K-12 Engineering Curricula through Partnerships with University Students and Industry

Suzanne A. Olds<sup>1</sup>, Chirag D. Patel<sup>1</sup>, Bugrahan Yalvac<sup>2</sup>, David E. Kanter<sup>1,2</sup>, Neha Goel<sup>1</sup>

<sup>1</sup>Biomedical Engineering Department/ <sup>2</sup>School of Education and Social Policy  
Northwestern University, Evanston, IL

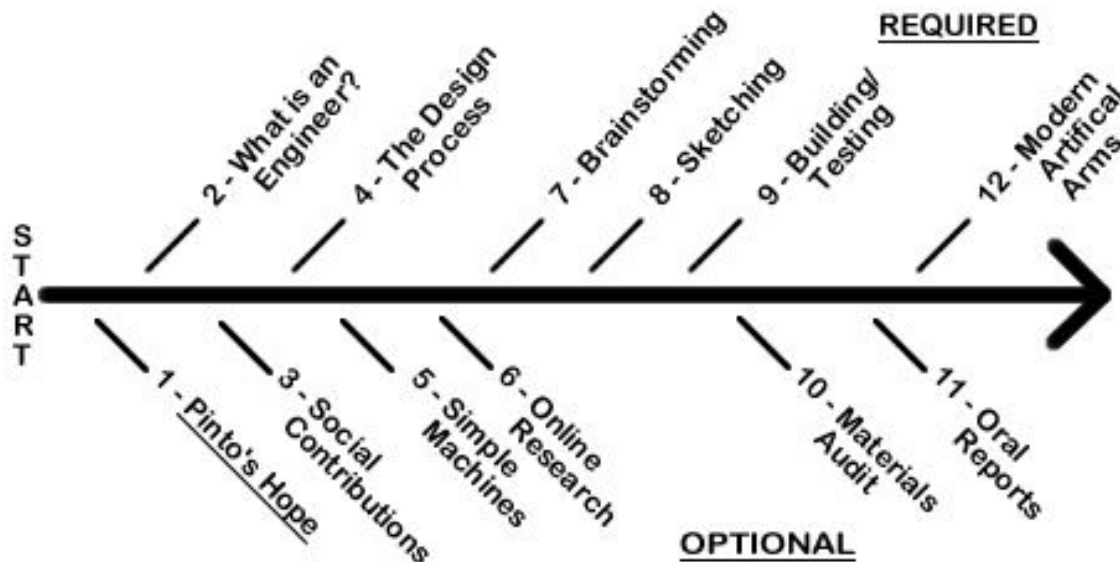
### Background

We have developed a K12 engineering outreach project that aims to benefit the project developers as much as the target recipients of the instructional materials. The primary developers in this case are university biomedical engineering (BME) students, both undergraduate and graduate. One objective for this project is to increase the developers' abilities to design instruction materials for teachers and students that are consistent with the research and theory on How People Learn<sup>1</sup>. Another objective is to increase the depth of BME students' content knowledge. The university students have partnered with university faculty, industry experts, and K12 teachers to develop a 3-week engineering module. The module challenges middle school students to draw on previously learned scientific principles as they design and construct prosthetic arms to accomplish tasks requiring either strength or fine motor control. The group's affiliation with the Center for International Rehabilitation has led to the creation of a 3-week program that meets state and national education standards and introduces students to the societal benefits engineering brings. In this paper, we will discuss: 1) our development model, 2) gains to university student developers, and 3) the effectiveness of this module for middle school students.

### Development Model

In conventional science and technology education, many K12 students do not have the opportunity to learn about engineering until they attend college and are faced with choosing a major. Similarly, many university students do not engage in activities to increase their understanding of teaching and learning at any point during their student careers. In an attempt to reverse these trends, university engineering students at Northwestern University have taken on the role of K12 curricular materials developers. An engineering faculty member and an education/engineering faculty member at Northwestern University who are both involved in the NSF-sponsored VaNTH Engineering Research Center encouraged university students to volunteer extracurricular time to develop a challenge-based module that would engage middle school students in the engineering design process<sup>2</sup>. Middle school science teachers, faculty from the school of education, and faculty from the school of engineering helped round out the initial working team. About 30 undergraduate and graduate science and engineering students have worked together for about 2 years to develop a 600+-minute module that challenges middle school students to draw on previously learned scientific principles as they design and construct prosthetic arms to accomplish tasks requiring either strength or fine motor control. The module (Project Prosthesis: Helping Hands, *PPHH*) has a literature component and integrates instruction in social sciences, math, science, and language arts. It meets state and national education standards and also demonstrates to students the real societal benefits engineering can bring.

Currently, the module's lessons are divided into units. These units are categorized into two groups (Figure 1). The first group consists of components we have deemed critical in meeting the main instructional objectives, and are therefore required for module implementation. The second group consists of optional components based in language arts, social sciences, and simple mathematics. These options allow teachers to complement the main engineering lessons and customize the module to fit their schedules.



**Figure 1 – A schematic of the constituent units of the PPHH lesson plans. The units across the top are required to achieve the overall objectives of the module. The units below the arrow represent optional units teachers can use to complement and provide contrast to the main engineering lessons.**

Alpha testing of the module took place from Spring 2002 – Fall 2004 with university students working with middle school teachers directly in the classroom. About 300 middle school students in 11 classes engaged in the project during this period. In the classroom, the university students took on several roles such as assigning and discussing homework, guiding the class through the curriculum, managing the time and structure of the class, and continually observing the students as they work. At the end of each lesson, the university students wrote a brief summary on the day's events and included their observations and analysis of how the activities were conducted and the outcome. This information, along with teacher interviews and assessment information (the students' homework and surveys), was used to continually improve the module between runs at various schools.

In February 2004, beta tests of the module, conducted without the presence of undergraduate or graduate student developers, will commence. An extensive teacher's guide, with lesson plans, instructional content, and instructional materials, has been developed to aid the teachers as they present and conduct the module in their classrooms. Additionally, the engineering students planned and conducted a teacher training session, and the students will be available via e-mail to answer any questions that might arise from the teachers during the implementation. These steps will allow for finalization and subsequent widespread dissemination of the module so teachers across the nation will be able to utilize the curriculum in their classrooms. Teachers may also

find detailed information about the module at:  
<http://www.cirnetwork.org/education/pphh/index.cfm>.

### **Benefits Gained by Student Developers**

A key goal of this project is to raise university students' awareness and understanding of teaching and learning. University students' experiences with the project were explored using an open-ended survey. Analysis of these surveys reveals that we have successfully accomplished our objective and that the engineering students have benefited in a number of ways. These benefits can be summarized as 1) better understanding the engineering design process, 2) enhanced communication, management, and leadership skills, 3) increased interest in teaching, and 4) increased opportunities to work with peers.

When asked to comment on how they felt their participation in the project has benefited them, 90% of the responding university students stated that the project has helped them better understand and utilize the engineering design process that they have been taught in their classes. The following excerpt illustrates this comment:

*"Firsthand experience in designing the module over the past two years has given me the opportunity to gain a thorough understanding of the design process, in particular its application to BME related projects. Constant improvements in the module have further emphasized the design process and other concepts learned in BME classes."*

Furthermore, 80% of the students also indicated that participation in this project has helped them improve their communication skills:

*"My communication skills have greatly improved due to the amount of writing, face-to-face meetings, and phone conversations with teachers, I've had to do. I have met and worked with many teachers and have learned much about the profession as well as the considerations teachers much take into account when making decisions for the entire classroom (cultural, economic, intellectual difficulty, etc)."*

During the implementation stage, the engineering students were in constant communication with the middle school students they were teaching. The engineering students also feel that the project has enhanced their management and leadership skills. Participating students had the opportunity to lead and guide classroom discussions, and manage the structure and timelines of daily classroom activities.

Over 90% of the undergraduate engineering students mentioned that participation in this project has drawn their interest to teaching and curricular material development. In the statement that follows, a participant states his excitement about being exposed to career options that combine education and engineering:

*"My involvement in this project has me seriously considering graduate study in the learning sciences or a job in instructional design / educational consulting."*

Graduate students interested in becoming professors gained from this project. The analysis revealed that they feel that this project has helped them improve their teaching and classroom management skills. In their experiences with the project, they have learned to dissect the subject material and determine the most effective method of communicating that subject matter to the middle school students. Those students not planning to pursue careers in teaching also feel that the communication, management, and leadership skills they have acquired and sharpened throughout the design and implementation of this project will prove vital in other career choices.

Engineering students have found the project beneficial in helping them develop ties with their fellow peers. In fact, when surveyed, 100% of the students indicated that one of the main reasons they initially joined the project was so that they could interact with fellow BME students and faculty. The broad spectrum of students involved in this project, ranging from freshman to doctoral candidates, provided them opportunities to learn from one another and interact in a non-classroom setting. The excerpt below represents this opportunity:

*"I've had the opportunity to work with BME students on a project that is unlike any we would have in classes. Working with students on development and in the classroom really allowed me to see the person outside of an academic setting."*

### **Effectiveness of the Module**

This module has been successful in benefiting the target recipients as well. Various instruments are currently being utilized to explore the effectiveness of the module in terms of teaching middle school students the design process and piquing their interest in engineering. A pre-project and a post-project homework assignment is one of those instruments. In this assignment, the middle school students are assigned a task in which they are asked to utilize the engineering design process. Students' homework assignments are collected and then scored in order to assess the effectiveness of the module. In particular, the homeworks are assessed using a rubric based on the engineering design process. Assessment data show significant gains in the middle school students' ability to carry out the following steps of the engineering design process: 1) identifying the initial problem, 2) brainstorming new features for their final design, 3) providing evidence to support their chosen features, and 4) drawing the final design in detail. A slight decrease is observed in the accuracy with which the students drew their final designs. Consequently, a component on engineering sketching has been added to the curriculum.

Another assessment and developmental instrument that we used was pre- and post-project surveys designed to explore participating students' views on engineering as well as to assess science content knowledge, specifically regarding simple machines. The analysis revealed that participation in this project has increased students' interest in studying engineering fields. A primary reason why students' interest has increased is that they have gained a better understanding of the field after their participation in the project. Also, the survey findings reveal that student interest in designing new things and working in teams significantly increased.

### **Discussions and Implications**

The findings of this study show that participating university BME students and middle school students gained various skills and expertise, which they often don't have the opportunity to acquire through conventional university and K12 education.

University BME students will be leading the theory and applications within the BME field. It is particularly important for them to understand people's approaches to and views toward the knowledge generated in the discipline. When we consider that today's BME students will be the future developers of BME curricula in both K12 and higher education levels, a thorough understanding of students' needs and expectations becomes crucial. Having experiences on how students learn will gradually help the future BME experts to effectively communicate with society, in general, and teachers, students, and parents, in particular.

The target recipients of this project, middle school students, have also gained skills and knowledge that they rarely have a chance to attain through traditional K12 science education. In addition to studying the engineering design principles and the BME subject matter, participating middle school students are encouraged to think about the relationships among science, technology, and society. The challenges utilized in the *PPHH* module represent the role of engineering in providing solutions to everyday problems. When students are challenged to find solutions to problems that result from war, they are led to think about the social aspect of science and engineering that conventional education lacks. Designing artificial limbs for the living victims of war may draw students' attentions to how engineering design principles can help people to live better. The *PPHH* module can be an effective way of engaging students to think about the relationships between engineering and society.

As mentioned before, this project is an ongoing collaboration of university students, K12 teachers, university faculty, and industry. In the next phases of our effort, we plan to 1) collect participating middle school teachers' views toward the designed instructional materials and their classroom implementations, 2) assess K12 students' gains, and 3) finalize the revisions of the curricular materials based upon teacher feedback and the results of the assessment data. Our final step in this project is to disseminate the designed instructional materials in K12 and higher education.

### **Acknowledgment**

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

### **Bibliographic Information**

<sup>1</sup>Bransford, J., Brown, A., & Cocking, R. *How People Learn: Brain, Mind, Experience, and School*. Washington, DC,: National Academy Press, 1999.

<sup>2</sup> S.A. Olds, D.E. Kanter, A. Knudson, and S.B. Mehta "Designing an Outreach Project that Trains Both Future Faculty and Future Engineers". Proceedings of the American Society for Engineering Education (CD-ROM DEStech Publications) Session 1609: 5 pages (2003).

## Biographies

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. She is the faculty advisor for the Biomedical Engineering Society undergraduate chapter and a director of BioOpportunities (an organization that prepares and informs PhD students and post-docs about career opportunities).

CHIRAG D. PATEL is a senior biomedical engineering student at Northwestern University. He has been involved in this project since its inception and is currently the project manager. Upon graduation, he plans to pursue graduate work in the Learning Sciences or work in industry.

BUGRAHAN YALVAC is currently working as a postdoctoral fellow in assessment studies for the VaNTH ERC, at Northwestern University. He holds B.S. degrees in Physics and Physics Education and an M.S. degree in Science Education from METU, Ankara. For his Ph.D. studies at Penn State, he majored in Curriculum and Instruction and minored in Science, Technology, and Society (STS).

DAVID E. KANTER is an Assistant Professor (Research) in the School of Education and Social Policy (Learning Sciences) and Research Associate in the Biomedical Engineering Department at Northwestern University. David heads up NIH-funded Minority K-12 Initiative for Teachers and Students (MKITS) and Science Education Partnership Award (SEPA) projects.

NEHA GOEL is a senior biomedical engineering student at Northwestern University who has been engaged in this K-12 outreach project since its inception. She has received a Ford Grant to work on this project and manages the assessment portion of the module. She has also actively recruited new students. She plans to attend medical school after she graduates.