2006-1282: FIRST-YEAR ENGINEERING PROGRAMS AND TECHNOLOGICAL LITERACY

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First-Year Engineering Programs and Technological Literacy

I. Abstract

The importance of technological literacy is briefly reviewed. The remainder of the paper focuses on the promotion of technological literacy through connections with first-year engineering programs: involvement of engineering faculty and students in K-12 classrooms, the involvement of engineering faculty and graduate students in K-12 teacher preparation, and engineering faculty involvement in improving the technological literacy of college students.

II. Technological literacy and why the engineering profession is concerned about it

Technological literacy is the ability to use, manage, assess, and understand technological systems,¹ requiring both knowledge and skills.^{2,3} Technological literacy could be used as a common theme to make connections among school subjects.⁴ The National Academy of Engineering report *Technically Speaking: Why All Americans Need to Know More about Technology* argues American adults and children have a poor understanding of the basic characteristics of technology, how it influences society, and how people can and do affect its development.⁵ Educators and policy-makers in the United States have been slow to acknowledge the importance of technological literacy. The general public, however, believes that development of technological literacy is important. The Gallup Organization, commissioned by the International Technology Education Association (ITEA), determined that:⁶

1. The American public is virtually unanimous in regarding the development of technological literacy as an important goal for people at all levels.
2. Many Americans view technology narrowly as mostly being computers and the Internet.
3. Near total consensus exists in the public sampled that schools should include the study of technology in the curriculum.

Technology education is weak at the elementary level and generally offered only as a specialization in secondary education. Change in the status quo will be slow because of a shortfall of qualified technology teachers and technology teacher education programs.⁷ The National Science Board charged the United States government “to attract and retain an adequate cadre of well-qualified pre-college teachers of mathematics, science, and technology.” The report’s recommendations include:⁸

- To make pre-college teaching more competitive with other career opportunities, resources must be provided to support programs in teacher preparation at institutions that succeed in integrating faculty and curricula of schools of engineering and science with schools of education; and
- To improve effectiveness of pre-college teaching, stakeholders must collaborate to support outreach efforts to K-12 by science and engineering professionals to motivate high quality curricular standards and expand content knowledge for classroom teachers and support research on learning that better informs K-12 mathematics and science curricula and pedagogy development.

At the K-12 level, the ITEA has defined Standards for Technological Literacy (STL) spanning five areas: The Nature of Technology, Technology and Society, Design, Abilities for a Technological World, and The Designed World.¹ The STL includes detailed standards that are parallel in format to the Curriculum and Evaluation Standards for School Mathematics published by the National Council of Teachers of Mathematics⁹ and the National Science and Education Standards published by the National Research Council.¹⁰

In higher education, researchers at Hope College surveyed non-technical majors enrolled in “Science and Technology of Everyday Life” in Fall 1998 to determine what types of information they would like to learn regarding science and technology. The survey data were supplemented by short essays by the students and data from focus groups. The responses indicated a desire for practical information and skills needed to live in a technological society. Particularly, students wanted the ability to understand what is wrong when technology breaks down and technical knowledge to inform their role as technology consumers. Specific topics of interest included the automobile, the computer, and common household technology.¹¹

III. First-year engineering involvement in K-12 schools

There has long been interaction between engineering faculty and students and the public school system. Once, this took the form of pro-bono support to help provide enriching experiences for students as well as outreach for the purposes of recruitment. This activity was scattered and largely undocumented. As the flattening and decline of engineering enrollments and graduations from 1985-1995 raised concern for the ability of US engineering schools to provide enough engineering graduates to support economic growth,¹² engineering faculty and student with the public schools focused more on recruitment to ensure that students considered pursuing STEM majors in college. The National Science Foundation’s Graduate Teaching Fellows in K-12 Education (GK-12) program, started in 1999, supports both the enrichment of K-12 education and the recruitment of students to STEM majors as well as K-12 teacher development and strengthened partnerships between institutions of higher education and local school districts.¹³ Whereas NSF’s GK-12 program helped put engineering students in the K-12 classroom, the Bridges for Engineering and Education (BEE) program helped forge engineering-education partnerships within and outside universities. Various partnerships were expressed as direct involvement in K-12 teaching or curriculum development and as teacher preparation programs.¹⁴

Some efforts are directed at engaging engineering faculty and students in curriculum development. North Carolina State University engineering students were placed in elementary schools in Wake County to prepare them to develop curriculum development in physics, engineering and math with the goal of increasing interest in STEM disciplines as well the development of curriculum that integrates science, technology and engineering topics with math, reading and writing.¹⁵

In-service teacher development extends the reach of engineering colleges into classrooms engineering faculty and students do not visit directly. Michigan Tech offered an introduction to engineering workshop for in-service teachers that allowed them to participate in engineering explorations in civil, environmental, chemical, computer, electrical, mechanical, materials,

geological, and mining engineering, much the same way matriculating engineering students are introduced to these topics.¹⁶

In fact, some schools are designing first-year engineering curricular materials that are versatile enough to teach K-12 students. Tufts faculty have done extensive work developing teaching tools for use with LEGO™ Robotics. They combine the use of LEGO pieces and LabView™ to allow students to program robots and remote sensing devices and build kinetic sculptures. Students from K-16 have been motivated to extend their knowledge of math and science to improve their design, and graduate students have used the software to enhance data acquisition.¹⁷ The work at Tufts has empowered First Lego League, an competition introducing children around the world to the fun and experience of solving real-world problems by applying math, science, and technology.¹⁸

New Jersey Institute of Technology's Center for Pre-College Programs is a multi-faceted program that includes crossover interaction between first-year engineering and pre-college outreach to elementary and secondary schools. The Center was founded in the Chemical Engineering and Chemistry department. The involvement of first-year engineering in the pre-college efforts includes the use of first-year engineering design modules in secondary education, participation of engineering faculty and graduate students in in-service secondary teacher development, development of bridge programs to specific engineering disciplines, assignment of engineering graduate students to K-12 curriculum development, hosting K-12 science and engineering competitions.¹⁹

Each year at the University of Missouri Rolla, 300-400 first-year engineering students engage in a team design-build activity as a part of *Engineering Design with Computer Applications*, a required Basic Engineering course. Five-person teams receive some funding support in completing projects like a human-powered water pump, a portable bridge, a disc launcher, a bubble machine, and a hands-free pencil sharpener. In spring 2003, the course objectives were extended to develop educational materials for the K-4 classroom including designing and building a device and an accompanying educational game or activity. The extension of the Basic Engineering course was sponsored by a Bridges for Engineering Education grant.²⁰

IV. First-year engineering involvement in K-12 teacher preparation

A City College of New York program involved engineering students in classroom teaching, which sparked an interest in education in nearly participants and encouraged some to pursue teacher certification and a teaching career. As part of the project, a simpler path for engineers to obtain teacher certification was crafted. Whereas an engineering student would once have been required to take 15-20 additional science or math credits and 18 education credits to be certified in science or math (and an entirely new undergraduate degree program for certification as a technology teacher), the simplified certification would require graduates of ABET-accredited engineering programs to complete 12-15 appropriate credits in Education (including a specially designed 6-credit project-oriented technology education class), plus student teaching.⁷ Michigan Tech researchers offered 80 dissatisfied engineering students an internship program as a path to a teaching career, and about half pursued teaching careers after the internship. This program was

followed by the development of a four-year program that allows students to earn a Bachelor of Science in Engineering and Teacher Certification simultaneously.^{16,21}

Whereas convincing engineering graduates to become teachers is one way to address the shortage of qualified teachers, it is more common for engineering faculty to become involved in developing the technological literacy of K-12 pre-service teachers through teacher preparation programs. Michigan Tech has also pursued this avenue through a partnership of the College of Engineering, the School of Technology, and the Department of Education. “Engineering Applications in Math and Science” was developed for pre-service teachers across disciplines and Technology and Design, a new teaching and certification minor, was developed for students pursuing math or science certification.¹⁶

Tarleton State University introduced first-year engineering students to pre-service teacher preparation in fall 2002. The first-year engineering students explained and demonstrated fundamental physics concepts to pre-service teachers were seniors taking *Curriculum and Methods for Early Childhood Through Grade 4 II: Mathematics and Science*. The pre-service teachers then shared these lessons with in-service kindergarten teachers. In addition to the service they provided the current and future K-12 teachers, the engineering students benefited by learning to communicate physics concepts to non-engineers by relating those concepts to everyday experience.²²

Western Michigan University used a BEE planning grant to develop an engineering-education collaboration to create a section of the first-year engineering course *Introduction to Engineering and Technology* to be taken by engineering and elementary education majors.²³ The course had goals for elementary education majors—describing the work of engineers and technologists for future advising, transforming science knowledge through application, developing a tool or apparatus for the classroom and an activity using it, and building connections to the Michigan Science Benchmarks—and a separate set of goals for engineering students—gaining client / customer experience and learning skills fundamental to success in studying engineering and technology. Students in “Teaching Elementary School Science” and “Practicum in Science and Mathematics Teaching” in Spring 2004 evaluated the work of *Introduction to Engineering and Technology* students from the previous semester, who were asked to create instructional devices to related to electromagnetism and create activities to investigate phase change.²⁴ The Western Michigan engineering-education collaboration led to a partnership in which more advanced engineering and education students designed and built K-12 instructional devices.²⁵

The University of Wisconsin-Platteville used support from a BEE grant to offer an experimental section of *Introduction to Engineering Projects* to nine pre-service teachers in secondary- and middle-level mathematics education. *Introduction to Engineering Projects* is a 1-hour class required of all first-year engineering students. The researchers aimed to help pre-service teachers acquire content knowledge useful in creating lessons and gaining an insight into the profession that would help them encourage students later. Pre-service teachers enrolled in the experimental section were required to attend additional bi-weekly seminars. Those seminars, journal entries, and in-class work, and exams were used to monitor the progress of the students, showing that education students performed consistently with first-year engineering student. The education

students were better leaders and oral communicators than the engineering students in general. Both of these may be because the non-engineering students are a self-selected population.²⁶

The University of Florida used materials and activities from its first-year Introduction to Engineering course to develop pre-college outreach programs middle and high school groups as well as for summer in-service teacher development through the summer institute of the Southeastern Consortium for Minorities in Engineering (SECME). The same materials were used to educate engineering alumni about the state of first-year engineering in the college.²⁷

V. First-year engineering involvement in teaching technological literacy in college

Many colleges and universities now have science, technology, and society courses a part of their general education requirements. There are too many courses of that nature to list them here. Keeping with the focus of this paper, here we focus on college courses promoting technological literacy that have a substantial link to first-year engineering programs.

The United States Military Academy core curriculum requires that all graduates develop a basic knowledge of physical systems. A five course engineering sequence ensures that all graduates are technologically literate at a high level. The approach gives non-engineering students an appreciation for various engineering topics from the first and second year.^{28,29} The United States Naval Academy has a similar core curriculum.³⁰

Since 2002, the University of New Haven has offered a first year engineering course intended for engineering and non-engineering students. *Introduction to Engineering* is project based and required of first-year engineering students, who develop a basic foundation of engineering knowledge in addition to developing problem solving, teamwork, and technical communication skills. Non-engineering students typically enroll in the course later on and learn about the engineering approach to problem solving and about the role of engineering in society.³¹ The University of New Haven implementation used attitude surveys, pre- and post-project testing, exams, oral presentations, written project reports, individual reports, in-class participation, homework, team self-evaluations, and school course evaluations to investigate the effectiveness of the course and the attitudes, retention, academic development, and problem solving and team skills of the students.³²

The University of Wyoming's one-hour Introduction to Engineering is also open to non-engineering majors, satisfying the Wyoming's University Studies Program (USP) requirements of developing information literacy and participating in "intellectual communities." While the course is open to non-engineering majors, it is required of all engineering majors. The authors indicate that approximately 25 non-majors enroll in this class, which meets in 12-14 sections of 20-22 students each, so a section would not be expected to have more than 2 non-majors (10% of the class).³³

The University of Arkansas at Little Rock introduced *Introductory Experience in Technology and Computers*, a project-based experiential course with a three-fold purpose—non-engineering majors are informed about the engineering profession, some students without a declared major are recruited to an engineering technology major, and engineering technology majors learn

fundamental skills to make them more success in their later studies. The course uses a magnetic ball levitator as a central theme, culminating in a design-build activity. A just-in-time approach is used to teach students the knowledge and skills they need to proceed on the project. The course has met at least one of its objectives—89% of students surveyed responded that the course “enhanced their interest in engineering.” This program is another sponsored by a Bridges for Engineering Education grant, and was developed through a collaboration of faculty in the College of Information Science and Systems Engineering and faculty in the College of Education. The project also focuses on improving engineering content in K-12 education through the development of engineering courses for pre-college educators, education majors, high school students, and to non-engineering university students, but only this course is documented.^{34,35}

Faculty in Santa Clara University’s Computer Engineering program offers a course for non-engineering majors that is based on two first-year computer engineering courses and that provides valuable information for outreach efforts. *Understanding Digital Technologies* satisfies a Technology component of Santa Clara’s general education requirements. The course provides a testbed for multimedia (text / animation) courseware modules in network concepts and introductory logic design, evaluating their effectiveness for use in outreach efforts to non-technical students in this course, in other courses at the university, and outside the university.³⁶

This section of the paper omits a large number curricular innovations that focus on making engineering students well-rounded rather than on making non-engineering students more technologically literate.³⁷

VI. Conclusion

There is evidence that the interaction of first-year engineering programs in the improvement of technological literacy is widespread. These interactions have diverse motivation (promoting technological literacy, recruiting engineering and technology students, and curriculum evaluation) and diverse approaches (classroom teaching, pre-service and in-service teacher development, and college courses for non-majors). The dissemination of work in this area is dominated by publication in refereed conference proceedings, most likely reflecting the fact that the effort of developing such work for journal publication is not likely to be recognized in the reward structure of most engineering colleges.

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