ENGINEERING STUDENTS TEACHING AFTER-SCHOOL ENRICHMENT PROGRAMS: A WIN-WIN PROPOSITION

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Abstract *— Michigan Technological University has received funding from the National Science Foundation to develop a Bachelor of Science in Engineering degree along with secondary teacher certification. Through this grant an internship program for engineering students has also been developed with twin goals: 1) providing local K-12 students with exciting, hands-on experiences in math, science and technology education, and 2) providing engineering students a chance to work with K-12 students to determine if a teaching career is of interest to them. The engineering students involved in this program have been conducting after-school enrichment programs for elementary students with sessions titled "Science Explorers," "Chemistry for Kids," "Amazing Animals," and "Forest Fun." The internship program is viewed as a mechanism to attracting engineering students to the teaching profession by providing them with firsthand experiences in working with young people in an educational setting. This paper will describe the internship program as well as our four-year engineering degree program that includes teacher certification.*

Index Terms — engineering programs, K-12 education, secondary teaching.

BACKGROUND

In 1996, through a project sponsored in part by the NSF and by NASA, the International Technology Education Association (ITEA) published its report: *Technology for All Americans: A Rationale and Structure for the Study of Technology* [1]. This report sets a goal of technological literacy for all citizens. Technological literacy is further defined as the ability to "use, manage, and understand technology." A citizenry that adequately understands technology will make better decisions about technological devices and information systems. In a democracy, where citizens routinely make decisions regarding the environment, medical ethics, land use, and defence, it is important that all citizens are technologically literate to some degree.

In today's society, technological literacy is confined mostly to those people who are directly working in technological fields such as engineering, manufacturing, science, or mathematics. The vast majority of American citizens have little or no comprehension of basic concepts in today's technological society nor can they fully understand the technological issues that are a part of the daily news. Traditional pre-college education has largely ignored technology as a core subject. Students take courses in math, science, social science, art, etc., but they rarely, if ever, take courses where they are exposed to the design process, ethical choices in the use and development of technology, or how engineers and technologists use mathematical and scientific principles in the solution of society's problems. A lack of instruction and understanding of technological issues will seriously hamper the ability of future citizens to keep pace with the ever-expanding role of technology in all facets of their lives.

The U.S. is also facing a severe shortage of individuals who are qualified and/or able to teach math and science in the K-12 system. The shortages are particularly great in the middle school grades as well as in urban school districts. The need for qualified K-12 math and science teachers is well documented in the Glenn Commission Report, "A Nation at Risk" [2].

In 1999, Michigan Tech received funding from the National Science Foundation to develop a program whereby a student could pursue teaching certification along with an engineering degree, all within a standard 4-year period of study. Clearly a person who has been educated as an engineer and who has been certified to teach is uniquely positioned to develop and implement meaningful technology units at the K-12 level. A program such as this would provide students the opportunity for a great deal of flexibility over their working career. For example, a person could graduate from this program and work in industry for a few years before switching to a career in teaching. Alternatively, a graduate of this program could teach full-time and work as an engineer over the summer months or as a consultant during his/her own time. Another option might be that a graduate of this program could teach for a few years and then switch to a career in industry. Still other possibilities exist for individuals with this unique set of qualifications.

There are several factors in the preparation of an engineer that will make him/her an exceptional teacher. Engineers typically have strong math and science backgrounds, have experience working on collaborative teams, routinely work on open-ended problems, have participated in a number of hands-on learning experiences, and have learned how math and science principles are applied in the solution of real-world problems. With the current emphasis on "prob-

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lem-based learning" in the K-12 system, we believe that engineers and engineering students can play a pivotal role in reshaping instruction in pre-college math and science courses. Further, virtually all of the state and national standards for teaching math and science stress application and integration--something that engineers have been trained to do from the start.

Due to the high degree of flexibility afforded by this program, we believe that it will likely be appealing to women and persons from underrepresented groups. In particular, women, who are more apt to be concerned with issues in combining a family with a career, may wish to have a career path where they work in industry gaining valuable experience and then migrate to a teaching career when they wish to start a family. Certainly a teaching career, where a person's schedule is aligned with that of his/her children, and where there are few demands in terms of out-of-town travel, is likely more amenable to providing a quality family life than an engineering career may be. Students from underrepresented groups, who oftentimes want to give something back to the community they grew up in, may be interested in a career where they can be successful engineers and also teach in their local school systems, providing younger students with mentors and role models.

PROGRAM STRUCTURE

According to ABET standards, in order for an engineering program to be accredited, students must complete the following coursework:

- One year of a combination of college level math and basic sciences (some with experimental experiences) appropriate to the discipline
- One and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study, and
- A general education component that complements the technical content of the curriculum and is consistent with the program and the institution objectives.

In addition, there are student outcomes that must be achieved and the program should be continuously monitored and improved through adequate assessment practices. In designing the new structure of our BSE program, we had to ensure that these minimum standards were achieved in order to satisfy the accreditation criteria.

The basic structure of the BSE degree program is outlined in the following (it should be noted that students can pursue the BSE without teacher certification also):

- **Mathematics and Science Core** consisting of Calculus I & II, Linear Algebra, Differential Equations, Statistics, Chemistry and Physics (23 credits). Students take an additional 9 credits in math/science electives. The elective courses they take for this core depend on prerequisites for their emphasis area coursework or for the courses in their minor/certification area. Students pursuing teacher certification are encouraged to take College Geometry as one of their elective math courses.
- **General Education Core** consisting of four required courses and five elective courses (28 credits total). Coursework in the General Education core are mandated by university policy, however, some of the elective courses may be "double-counted" towards minor or certification requirements.
- **Engineering Core** consisting of two first year engineering courses, a semester of Senior Design, Statics and Mechanics of Materials, Thermodynamics and Fluid Mechanics, Materials Science, and Electrical Circuits and Instrumentation. In addition, students take a course in "design implementation"--either a construction or a manufacturing course depending on emphasis area.
- **Engineering Emphasis** area that consists of upper-level courses in a specific engineering discipline. Courses in the emphasis area have been selected to enable students to pursue graduate studies in a given discipline or to prepare students for work in industry upon graduation. The coursework in the Engineering Core and the Engineering Emphasis area must total 48 credits.
- **Directed Electives** in the form of either an approved university minor or a certification area. Approved minors on campus are typically 16-18 credits and approved certification areas (including teacher certification) are around 24 credits.

For students pursuing teacher certification, there are a total of 31 credits required *including* 12 credits of student teaching, however, two courses (6 credits) can count towards a student's General Education core as electives. Thus, for a student pursuing a BSE with teacher certification, the total degree requirements are 133 credits, which is possible in four years' time (around 33 credits per year) although it may be difficult.

Students in the BSE program are strongly encouraged to pursue a Master of Engineering degree, a new professional degree program we have established, that can be completed in just one year of coursework with a 3-credit practicum. As part of the MEng degree requirements, a student can complete up to 12 credits of senior-level coursework meaning that students in the BSE could go back and take some of the courses they didn't take from the discipline in their emphasis area to "round out" their preparation. In this way, students can receive an accredited undergraduate engineering degree, secondary teacher certification, and a Masters' degree all within five years' time. In contrast, if they were to follow a traditional degree path in one of the disciplines, it would take five years just to obtain their BS degree and secondary teacher certification.

TEACHING QUALIFICATIONS

In the state of Michigan, teachers at the secondary level are qualified to teach in their major as well as in their teaching

minor (teaching minors and university minors are not generally the same thing). Students who completed the BSE program along with teacher certification would automatically have a teaching major in Technology and Design. The Technology and Design teaching area is relatively new within the state and is similar to a pre-college engineering curriculum. Table I lists the five major categories for the standards for Technology and Design K-12 education along with the 20 specific standards emanating from each grouping [3]. Benchmarks for meeting the standards also exist at each grade level in the K-12 system.

TABLE I
TECHNOLOGY AND DESIGN EDUCATION STANDARDS

Category	Relevant Standards
The Nature of Technology	The characteristics and scope of technology
	The core concepts of technology
	The relationships among technologies and the connections between technology and other fields
Technology and Society	The cultural, social, economic, and political effects of technology
	The effects of technology on the environment
	The role of technology in the development and use of technology
	The influence of technology on history
Design	The attributes of design
	Engineering design
	The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving
Abilities for a Technological World	Apply the design process
	Use and maintain technological products and systems
	Assess the impact of products and systems
The Designed World	Medical technologies
	Agricultural and related biotechnologies
	Energy and power technologies
	Information and communication technologies
	Transportation technologies
	Manufacturing technologies
	Construction technologies

INTERNSHIP PROGRAM

In an effort to recruit students into the BSE program, an internship program has been implemented through the Western U.P. Center for Science, Mathematics, and Environmental Education (WUPCSMEE) for undergraduate engineering students at Michigan Tech. Through this program, approximately 15 engineering students each semester are selected to conduct a variety of after-school enrichment programs in area schools. The after-school programs are conducted in weekly classes of 4-6 week sessions. Michigan Tech students travel to two assigned schools each week and meet with 15-20 students for approximately 90 minutes. During the class, they conduct fun hands-on experiments and discuss the science "behind" the activity. Table II lists the various sessions offered by Michigan Tech students over the 2001-02 academic year.

TABLE II
AFTER-SCHOOL ENRICHMENT PROGRAMS OFFERED BY MICHIGAN TECH ENGINEERING INTERNS

Title	Grade Levels	Number of Students Served
Alternative Energy LEGOs	4-6	90
Amazing Animals	1-3	166
Chemistry for Kids	4-6	75
Forest Fun	K-6	205
Science Explorers	1-3	156
Science Explorers	4-6	172

Although not all topics in these after-school programs are directly related to engineering, they are designed to provide young children the opportunity to have fun "doing" science. The activities that the children complete have been compiled from many resources [4-9], and also include some innovative activities developed by the Michigan Tech students. Detailed lesson plans and equipment kits for each session have been compiled enabling the Michigan Tech students to focus more on their teaching and spend a minimal time in preparation for each session. Of the various after-school programs offered, Science Explorer sessions have the most significant engineering "flavor." Outlines for the two Science Explorer sessions are shown in Tables III and IV.

PROGRAM EVALUATION

The results from the internship program were evaluated on several levels. Michigan Tech engineering students who par-

TABLE III
SCIENCE EXPLORER PROGRAM FOR GRADES 1-3

Week	Activities
1	Why Planes Fly: Ping Pong Puffer [4], Controlled Flight, In a Spin
2	Observations and Comparisons: Science in a Bag [5], Mystery Powders, What Makes Paste? [6]
3	Characteristics of Objects: Magnetic Attraction, Magnetic Strength [7], Separating Mixtures, Sifting Sand and Beans
4	Sound: Vibration, Frequency and Pitch, Slinky Sound Waves [7], Straw Oboes [8], Spoon Bell [7], Clucking Chicken [7], School Box Guitar [4]
5	Forces: Balancing Stick [4], Balloon on a String [4], Forces and Motion [4]
6	Engineering Forces: Tug-Push-Twist-O'War [8], Straw Shapes [8], Spaghetti Towers

TABLE IV
SCIENCE EXPLORER PROGRAM FOR GRADES 4-6

Week	Activities
1	Structures and Strength: Straw Shapes [8], Spaghetti Towers, Gum Drop Bridges
2	Package Engineering & Design: Columns [8], Egg Drop, Mail-A-Pringle
3	Electricity: Hot [7], Conductor [7], Electromagnet [7]
4	Air Pressure: How can you feel the weight and pressure of air? [9], How hard can air push? [9], How can we measure atmospheric pressure? [9], How can air pressure help airplanes fly? [9]
5	Water Properties: Water Olympics, Under Pressure [8], How can you make a soap motorboat? [9]
6	Simple Machines: Ramps and Cars [4], Simple Machines

ticipated in the program were surveyed both pre- and post-experience and K-6 students and their in-school supervisors were also surveyed at the end of the session.

Intern Surveys

Statistical analysis of pre-/post-experience surveys for the engineering students who taught the after-school sessions showed an increase in their confidence, their interest in a teaching career, and their perception of the importance of teaching. The gains in attitudes towards each of these three factors were statistically significant ($p<0.005$). Representative comments from open-ended survey questions are:

- "Overall, it was an incredibly rewarding experience that didn't feel like work. Being able to go out to area schools and interact with the teachers and students was a great privilege, which I really enjoyed! Furthermore, this experience has allowed me to consider the possibility of becoming a teacher after having worked in the chemical engineering industry, which is something I would have never considered had I not participated in this opportunity."
- "I have very much enjoyed this teaching experience and look forward to teaching another group of students in the winter. It gave me such a warm feeling inside to see the joy on the children's faces when they would complete the activity."
- "I learned that being a teacher might be something that I would like to pursue sometime in the future. I learned how to break science concepts down into simple, easy ideas that young children could more easily grasp."
- "Participating in this program is by far the most exciting job I have ever had. Everyday that I presented a lesson to a class I learned something new. I thank you for this opportunity and I just hope that this class has benefitted the students I have taught as much as it has helped me."

K-6 Student Surveys

The elementary students who participated in the after -school programs were also surveyed regarding their experiences. The following results were obtained for the Forest Fun and Science Explorer programs.

Forest Fun: Grades 1-3
- 65% would have liked the program to last longer
- 80% wanted to take another class the following year
- 74% reported liking science more than they had before the program

Forest Fun: Grades 4-6
- 91% would have liked the program to last longer
- 100% wanted to take another class the following year
- >75% of activities were well liked

Science Explorers: Grades 1-3
- 100% would have liked the program to last longer
- 93% wanted to take another class the following year
- 96% reported liking science more than they had before the program

Science Explorers: Grades 4-6
- 91% would have liked the program to last longer
- 93% wanted to take another class the following year
- 67% reported liking science more than they had before the program

Supervising Teacher Surveys

Supervisors were asked to rate their observations of the after-school science program. Questions were scored on a 10-

point scale and included items relative to the performance of the Michigan Tech students as a teacher and role model, the use of effective teaching techniques in the sessions, and the age-appropriateness of activities and topics. Average scores on the supervisor ratings were virtually all 10's with the lowest items being the use of "effective teaching techniques" (8.9) and the use of "effective classroom management techniques" (8.2). Supervisors overwhelmingly viewed the program as a valuable opportunity for students to enhance their knowledge of science (9.8) and their attitudes towards science (10.0).

CONCLUSIONS

Michigan Tech has successfully developed a 4-year program whereby undergraduate students can complete a Bachelor of Science in Engineering while simultaneously completing requirements for secondary teacher certification. An internship program was developed for engineering students to conduct after-school enrichment programs for K-6 students. The focus of the after-school programs is on improving children's attitudes towards and understanding of science and engineering. A secondary focus of the internship program was to interest engineering students in the possibility of a teaching career. Surveys completed by the engineering interns, the K-6 students, and the school supervisors indicate that the internship program is achieving its goals.

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