Toward a New Paradigm: A Bachelor of Science Degree with a Major in Engineering Education

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ABSTRACT

Existing efforts to introduce engineering into K-12 have traditionally consisted of in-service professional development activities for teachers, summer camp experiences for students and/or single day events in classrooms. A report from the National Academy of Engineering entitled "*Standards for K-12 Engineering Education?*" said that, "although theoretically possible to develop standards for K-12 engineering education, it would be extremely difficult to ensure their usefulness and effective implementation" at this time, in part because "there is not at present a critical mass of teachers qualified to deliver engineering instruction." Systematic change will require a new paradigm – teachers who have a fundamental understanding of engineering will provide the most effective, sustainable solution for the implementation of K-12 engineering education. The research question becomes: how can we introduce this necessary, systemic change into K-12?

Ohio Northern University (ONU) has announced a new Bachelor of Science degree with a major in Engineering Education. This program will provide a graduate with a foundation in engineering, mathematics and education, qualifying the graduate for licensure as a secondary math teacher in the state of Ohio. The degree is similar to a General Engineering degree, expanding potential career opportunities. This degree program offers the opportunity to introduce teachers into middle and high school environments with an inherent appreciation of engineering, producing graduates that are capable of truly integrating math, science, engineering analysis and design into the classroom.

Keywords: Engineering, STEM, STEM-Increase K-20 Interest and College Enrollment

BACKGROUND

Rationale

In the National Academies study titled *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (National Academy of Science, 2006), the authors noted that:

> *"Education in science, mathematics, and technology has become a focus of intense concern within the business and academic communities. The domestic and world economies depend more and more on science and engineering. But our primary and secondary schools do not seem able to produce enough students with the interest, motivation, knowledge, and skills they will need to compete and prosper in such a world."*

Our society is dependent on advances in engineering and technology, and the rate at which this dependency grows in increasing. The National Academies report goes on to describe the importance of advances in engineering and technology as crucial to the social and economic conditions and discusses changes that must occur in the K-12 education system to promote engineering and technology for the United States to compete, prosper, and be secure in the global community in the 21st century.

The American Society for Quality (ASQ) commissioned a market research firm to study teacher knowledge and passion for math and science (Meris, 2010). The results show that, while students consider their teachers knowledgeable about math and science, they do a poor job of discussing STEM careers and/or encouraging students toward the STEM disciplines. The study notes that:

> *"Although 85 percent of students said their teachers deserve at least a 'B' when it comes to knowledge about science topics (55 percent of students gave their teachers an 'A'), 63 percent of high school students said their teachers are not doing a good job of talking to them about engineering careers ('C' or lower), and 42 percent of high school students said their teachers don't ably demonstrate how science can be used in a career ('C' or lower)."*

The National Academies report *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* (National Academy of Engineering, 2009) cites three main goals driving their study:

1. There are multiple perspectives about the purpose and place of engineering in the K–12 classroom. These points of view lead to emphases on very different outcomes.
2. There has not been a careful analysis of engineering education within a K–12 environment that looks at possible subject intersections.
3. There has been little if any serious consideration of the systemic changes in the U.S. education system that might be required to enhance K–12 engineering education.

These goals describe the importance of a necessary, systematic change in the incorporation of engineering within K-12. Existing efforts to introduce engineering into K-12 have typically consisted of in-service activities for teachers and summer camp experiences and/or single day in-class events for students. Systematic change will require a new paradigm – the effectiveness of reaching out to teachers and students as individuals is debatable, but these methods are certainly not sustainable. Introducing teachers who have a fundamental understanding of engineering should provide the most effective, sustainable solution.

K-12 Student Misconceptions about Engineering

Middle and high school students are often unaware of the engineering profession; those students who are aware of engineering often misunderstand the role of engineers in society. This may be partially attributed to misconceptions held by those close to them in academic roles (teachers, school counselors); despite efforts to increase interest in engineering, these misperceptions persist. Teachers who are unaware of the importance of engineers in society may perpetuate their misconceptions, thus discouraging students from pursuing engineering.

Current studies of perceptions of engineering in K-12 show that students typically lack the most basic knowledge of engineering and what engineers do. Knight and Cunningham (2004) worked with students in first through fifth grades, and found that a large majority of students believed that engineers worked on cars. Fewer than one third of these students identified design as a characteristic of engineering. Reid and Floyd (2007) showed that introducing an authentic engineering activity into a seventh grade pre-engineering course changed the perception of engineering from "people who fix cars" or "people who build buildings" to people who create, solve problems and help society.

A study of various "draw a scientist" projects (Finson, 2002) shows when students are asked to draw a scientist and characteristics of the drawings assessed to determine characteristics of their perceptions of scientists, these pictures include many stereotypical results: engineers are usually portrayed as male, working in a laboratory wearing white lab coats. In one study involving the development and use of a similar Draw an Engineer Test

(Knight and Cunningham, 2004), many initial misconceptions included engineers as primarily train drivers or auto mechanics. Most student responses involved engineers building buildings or fixing car engines, and were nearly all male. This perception is most likely one factor contributing to a very low percentage of female engineering students.

K-12 Teacher Misconceptions about Engineering

A report of the American Society for Engineering Education (Douglas, et al., 2004) showed that teachers view engineering as a difficult to very difficult profession. When asked how many of their students could be engineers, 31% said “all” or “most”, while 69% said “some” or “few”. When asked how accessible engineering was for different groups, scores were much lower for females or minorities in engineering than any other profession. Teachers’ attitudes of engineering as a difficult profession which may not be suitable for most of their students may contribute to the stereotypical perception of their students.

Research shows that prospective K-12 teachers often have limited knowledge of processes by which scientific knowledge is generated (i.e.: the Nature of Science, or NOS), thus may have difficulty generating lessons in science that go beyond science as a collection of facts (Schwartz, 2004: Ledeman, et al., 2001). Teaching and developing content at a higher level of understanding as described by Bloom’s taxonomy (Bloom, 1969) such as application of or analysis of science (or engineering) require teachers to understand science (or engineering) at a higher level: synthesis or evaluation. Teachers with a perception of science as a collection of facts (comprehension level) would find it very difficult to instruct or assess students past this level.

Studies of epistemological beliefs of teachers toward science have been well documented (Hofer & Pinrich, 1997: Schwarta, et al., 2003: Khishfe, et al., 2001), however, little research has been done on understanding engineering or technology in K-12 teachers (Cunningham, et al., 2005). Taken as a whole, the understanding of science and engineering concepts and the nature of science and nature of engineering construct a definition of a level of technical literacy which is desirable within the population of K-12 teachers.

Engineering in K-12: Educational Standards

There are efforts to incorporate engineering into K-12 educational standards at a national level. The Committee on K-12 Engineering Education at the National Academy of Engineering met to finalize recommendations in the Summer 2009. The final report titled *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* (National Academy of Engineering, 2009) cited three principles:

Principle 1. K–12 engineering education should emphasize engineering design;
Principle 2. K–12 engineering education should incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills, and;
Principle 3. K–12 engineering education should promote engineering habits of mind.

Among the recommendations of the committee is Recommendation #4:

“The American Society for Engineering Education (ASEE), through its Division of K–12 and Pre-College Education, should begin a national dialogue on preparing K–12 engineering teachers to address the very different needs and circumstances of elementary and secondary teachers and the pros and cons of establishing a formal credentialing process.”

In short, the development of engineering standards for K-12 is not as much a matter of *if* as a matter of *when* and *how* they are to be implemented; as separate standards or incorporated into existing science or newly developed national mathematics standards.

Engineering Curricula in K-12

Project Lead the Way (PLTW), cited numerous times in the *Engineering in K-12 Education* report, is one example of a K-12 engineering curriculum seeing widespread adoption across the United States. While numbers of schools and students vary widely by state, over 500,000 students from over 3,500 schools have taken part in PLTW classes (http://www.pltw.org). Other programs, such as The Infinity Project and Engineering the Future, offer engineering within K-12 education environments although certainly not to the extent of the multi-year, multidisciplinary PLTW curriculum.

Teacher training for PLTW is consistent throughout the United States, although administered by different institutions in different states. Teacher licensure issues also vary from state to state, with Ohio offering one of the (if not the) broadest range of teachers able to teach PLTW courses – after attending and passing additional PLTW training.

A study conducted at Brownsburg Middle School in Brownsburg, IN (Reid and Floyd, 2007) showed a tremendous increase in an accurate perception of engineering as a helping profession. Fortunately, the Gateway to Technology course in which the project was implemented and the study was conducted was a required course for all students in the year of the study, and it is reasonable to assume that this more accurate perception was seen by students who intend to pursue engineering as well as those who do not. Opportunities like this are extremely rare.

Other programs designed to introduce engineering to K-12 students include one-time events such as summer camps or in-class demonstrations. A significant drawback to these activities is that they generally appeal to students who already have a perception of what engineering is, rather than changing a misconception or forming a perception of engineering in a student who is not necessarily predisposed to engineering – the intent of these programs is to reach *these very students*.

This raises the question: How can a true representation of engineering as a creative and innovative profession that helps society become ingrained into K-12?

Solving this problem accomplishes two goals:

1. Students must understand what engineering is to make an effective decision whether or not to study engineering
2. Accurately describing engineering in these terms should make it more appealing to a more diverse audience

Effectively integrating engineering into the classroom requires more than repeatedly reaching a handful of students in summer camp settings, and more than scattered in-service events for teachers (National Academy of Engineering, 2009): effective, engaged teachers who understand engineering will have a lasting effect on many students over a period of many years; in addition, they have an effect on other teachers and administrators.

The creation of a bridge connecting K-12 engineering and college requires teachers who understand and appreciate engineering. This degree program is the first step to a nationwide effort to produce those teachers.

BACHELOR OF SCIENCE: MAJOR IN ENGINEERING EDUCATION

The T.J. Smull College of Engineering at Ohio Northern University has introduced a new major, leading to a Bachelor of Science degree with a major in Engineering Education. The degree was approved by the Ohio Board of Regents in March 2011. It provides graduates with a foundation in engineering, mathematics and education, qualifying the graduate for licensure as a secondary math teacher in the state of Ohio. The degree is similar to a General Engineering degree available in some other Universities, expanding potential career opportunities to general engineering sales, training, and unique opportunities in venues such as Science and Technology museums. Students are being enrolled into the program starting in the Fall 2011.

Three graduate programs in Engineering Education have been successfully created in the last 6-7 years, with the primary goals of *defining the research agenda* and *conducting research* in engineering education. Creation of the program at Ohio Northern University allows ONU to help define similar undergraduate programs nationwide, helping to establish the agenda and outcomes for similar programs.

Plan of Study

This plan shows a four year degree with a number of credits equal to the other engineering disciplines at Ohio Northern University.

Engineering:
The plan begins with a core of engineering classes. Students are required to take a core of 19 credits in engineering, including a design-based introduction, first-year capstone, Circuits, Statics, Dynamics, and Strength of Materials or Material Science. Beyond the foundation courses, students will take a 4-course concentration in engineering. Students will work with their advisor to determine appropriate courses; students may select courses toward a concentration in robotics, general engineering, infrastructure, computers, etc.

The plan of study meets ABET accreditation requirements as specified for General Engineering and similar programs. The program will be submitted for accreditation as a general engineering program once there are graduates of the program (an accreditation requirement).

Mathematics:
The plan has the core requirements for a mathematics degree, including all subject matter covered in a Math Education plan of study. Much of the coursework is required of all engineering disciplines, making this partnership a natural fit.

Education:
The plan meets requirements for licensure in the state of Ohio to teach secondary math, including 41 credit hours and in-class teaching experience.

The plan of study is shown in Figure 1.

Ohio Northern University ***Engineering Education Major***
T. J. Smull College of Engineering ***Students Entering 2011-12***

FALL - Freshman	Crd	SPRING - Freshman	Crd
Engineering Orientation	0	Introduction to Engineering 2	3
Introduction to Engineering 1	3	Calculus 2	4
Writing Seminar	3	Physics 1	3
Calculus 1	4	Physics 1 Lab	1
Communication in the Classroom	3	5 Day Field Experience 1	1
Culture and Schooling	3	Exceptional Learners	3
	16		15

FALL - Sophomore	Crd	SPRING - Sophomore	Crd
Electric Circuits	4	Dynamics	3
Statics	3	Strgth of Materials or Eng Materials Sci	3
Differential Equations	4	Calculus 3	4
5 Day Field Experience 2	1	Foundations of Mathematics	3
Extra Disciplinary Seminar	3	Development Across the Lifespan	3
	15		16

FALL - Junior	Crd	SPRING- Junior	Crd
Statistics for Scientists & Engineers	3	Engineering Education 1	4
Computer Applications	3	Educational Psych & Instr Practices	3
Curriculum and Assessment	3	Literacy Across Content Areas AYA/MA	3
Foundations in Geometry	3	Technical Elective 2	3
Technical Elective 1	3	Technical Elective 3	3
	15		16

FALL - Senior	Crd	SPRING - Senior	Crd
Senior Design 1	3	Senior Design 2	3
Engineering Education 2	4	Leadership Seminar in Education	3
Abstract Algebra 1	3	Student Teaching - Adolescent	12
Integrated Mathematics Methods	3		18
Technical Elective 4	4		
	17		

FIGURE 1: ENGINEERING EDUCATION PLAN OF STUDY

STATUS AND FUTURE PLANS

Student Interest

The Engineering Education program was approved by the Ohio Board of Regents in March 2011. Unfortunately, this was late in the academic year to begin promoting a new degree program; however, a handful of students have heard of the program and have expressed interest. The first cohort of students will begin in Fall 2011 with 3-5 students expected in the first cohort.

Future Plans

The program is expected to allow us to further integrate the disciplines of engineering, education and mathematics. We anticipate developing and offering teacher professional development opportunities and workshops in the immediate future. We also anticipate disseminating success stories and hope to inspire other institutions to offer similar programs. Plans toward these ends are currently in development.

CONCLUSION

This new and innovative program in Engineering Education offers an opportunity for Ohio Northern University to introduce teachers into K-12 schools who have an accurate perception of engineering as a profession. These teachers will understand that engineering is more than just "math and science", but includes dimensions of creativity, innovation, help to society, and an entrepreneurial mindset. This is a major step toward a necessary, systemic change that must occur in order to have an effect on engineering within K-12. The effort will allow Ohio Northern University to help bridge the gap between K-12 engineering education and college and to help define "engineering" within K-12.

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