Bachelor of Science in Engineering Education: Differentiating from Traditional Education and Engineering Disciplines

Dr. Kenneth Reid, Ohio Northern University

Ken Reid is the director of First-Year Engineering, Director of Engineering Education and an Associate Professor in Electrical and Computer Engineering and Computer Science at Ohio Northern University. He was the seventh person in the U.S. to receive a Ph.D. in Engineering Education from Purdue University. He is active in engineering within K-12, serving on the TSA Boards of Directors and over 10 years on the IEEE-USA Precollege Education Committee. He was named the Herbert F. Alter Chair of Engineering in 2010. His research interests include success in first-year engineering, introducing entrepreneurship into engineering, international service and engineering in K-12.

Mr. Tyler J Hertenstein, Ohio Northern University

Hertenstein is a sophomore studying engineering education at Ohio Northern University, where he currently resides as president and co-founder of a student chapter of ASEE. Previously, Hertenstein has co-authored two papers for the 2012 ASEE North-Central conference. At ONU, Hertenstein is also involved in the Dean's advisory team, Alpha Lambda Delta, Phi Eta Sigma, the yearly STEM day, and Northern Engineers without Boundaries.

Mr. Graham Talmadge Fennell, Ohio Northern University
Elizabeth Marie Spingola

Elizabeth is a junior at Ohio Northern University. She is the Project Manager of an organization at school that is designing and fabricating a model Mars Rover for a local museum. She is, also, has leadership roles in Phi Sigma Rho, the engineering sorority at ONU. Other organizations she belongs to include SWE, ASME, Flute Choir, JEC, and more.

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Abstract:

Ohio Northern University is in its second year of an innovative and unique Bachelor of Science degree with a major in Engineering Education. This program will provide 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, expanding potential career opportunities. Further opportunities are expected to be among venues such as science and technology museums. This degree program offers the introduction of math teachers into middle and high school environments with an inherent appreciation of engineering, producing graduates who are capable of truly integrating math, science, engineering analysis, and design into the classroom.

The objectives of establishing this degree program include those that are directed toward our students as well as the profession:

- Assure graduates of a truly integrated education equipping them for success as engineers and/or educators, and
- Work toward changing the K-12 paradigm: effectively introduce engineering into K-12 by influencing the teaching profession.

One of the difficulties of establishing and completing a truly interdisciplinary engineering degree is addressing requirements from programs, departments and colleges different than typically found in engineering. For example, graduates must complete not only an engineering capstone project, but meet state requirements for student teaching. Challenges include incorporating effective classroom experiences, curriculum development and extracurricular opportunities available as students in an education program with more typical requirements from engineering disciplines such as required laboratories and opportunities for undergraduate research. Seeking accreditation for the program from the National Council for Accreditation of Teacher Education (NCATE) as well as ABET affords additional challenge.

This paper will describe the unique challenges of establishing this interdisciplinary and innovative program, including issues related to accreditation of the program from two perspectives: education and engineering. Further, the paper will present issues and opportunities from the perspective of students from the initial cohort, who have had an exceptional number and breadth of opportunities as the first students in the program.

Background: Establishing the Need

In the 2006 National Academies study entitled *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* [1], 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."

The American Society for Quality commissioned a market research firm to study teacher knowledge and passion for math and science. The results show that students feel their teachers do a poor job of discussing STEM (Science, Technology, Engineering and Math) careers and/or encouraging students toward the STEM disciplines, even though they consider their teachers to be knowledgeable about math and science:

> "Although 85 percent of students said their teachers deserve at least a 'B' when it comes to knowledge about science topics, 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)."[2]

The National Academies has issued reports on introducing engineering standards into K-12 [3,4]. The report *Standards for K-12 Engineering Education?* discusses the difficulty in effectively implementing engineering standards:

1. There is relatively limited experience with K-12 engineering education in U.S. elementary and secondary schools, and
2. There is not at present a critical mass of teachers qualified to deliver engineering instruction.

The effectiveness of working with individual teachers and students through workshops and classroom activities is debatable, but reliance on these methods certainly does not lead to sustainable change. A new paradigm, introducing teachers trained with an engineering framework, is a necessary step for systemic changes such as the introduction of engineering standards.

Overview

A few 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. By creating this program, Ohio Northern University has become one of the first in the nation to offer undergraduate degrees in each STEM discipline: Science Education, Technology Education, Engineering Education and Math Education.

The Engineering Education degree program offers an opportunity to introduce teachers into K-12 with an inherent appreciation of engineering, producing graduates that are capable of truly integrating math, science, engineering analysis and design into the classroom. Further, it provides a mechanism to strengthen pre-engineering programs like Project Lead the Way (PLTW) by producing additional teachers licensed and capable of entering PLTW training; teachers who can promote the value of engineering from "inside" the system.

Engineering Education Plan of Study

The plan of study has been approved by the Ohio Board of Regents and allows a student to obtain a four year degree with a number of credits equal to each other engineering discipline 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 work with their advisor to design a 4-course concentration in engineering. Students may select courses toward a concentration in robotics, general engineering, infrastructure, computers, etc. This course sequence provides depth in an area of interest to the student, but would not qualify the graduate to claim expertise in a specific discipline.

Mathematics:

The plan has the core requirements for a Mathematics Education degree, including all subject matter covered in the Math Education plan of study. Much of the coursework in math 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 AYA (Adolescent and Young Adult) mathematics, including 41 credit hours and in-class teaching experience.

New course development:

Two new courses are to be created as part of the degree. Engineering Education 1 covers the history of engineering and mathematics and the integration of technology in the classroom. Engineering Education 2 includes pedagogy, policy issues and introduces Model Eliciting Activities[5] and other curriculum development.

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

FALL - Freshman	Crd
Engineering Orientation	0
Introduction to Engineering 1	3
Writing Seminar	3
Calculus 1	4
Communication in the Classroom	3
Culture and Schooling	3
	16

SPRING - Freshman	Crd
Introduction to Engineering 2	3
Calculus 2	4
Physics 1	3
Physics 1 Lab	1
5 Day Field Experience 1	1
Exceptional Learners	3
	15

FALL - Sophomore	Crd
Electric Circuits	4
Statics	3
Differential Equations	4
5 Day Field Experience 2	1
Extra Disciplinary Seminar	3
	15

SPRING - Sophomore	Crd
Dynamics	3
Strgth of Materials or Eng Materials Sci	3
Calculus 3	4
Foundations of Mathematics	3
Development Across the Lifespan	3
	16

FALL - Junior	Crd
Statistics for Scientists & Engineers	3
Computer Applications	3
Curriculum and Assessment	3
Foundations in Geometry	3
Technical Elective 1	3
	15

SPRING- Junior	Crd
Engineering Education 1	4
Educational Psych & Instr Practices	3
Literacy Across Content Areas AYA/MA	3
Technical Elective 2	3
Technical Elective 3	3
	16

FALL - Senior	Crd
Senior Design 1	3
Engineering Education 2	4
Abstract Algebra 1	3
Integrated Mathematics Methods	3
Technical Elective 4	4
	17

SPRING - Senior	Crd
Senior Design 2	3
Leadership Seminar in Education	3
Student Teaching - Adolescent	12
	18

Figure 1: Engineering Education Plan of Study

Specific Requirements from Education Courses

Specific differences in the Engineering Education curriculum include courses in which field work is required. Two of the first courses in the curriculum are 5-day field experiences. These are designed to give extensive classroom experience, a very useful experience for those who may not have been in a classroom as a teacher. Each 5-day experience class is typically done during a break from university classes. Student requirements include typical experiences within a classroom such as handing out papers, interviewing school principals, reviewing course curricula and standards, and teaching a lesson. For the first 5-day, teacher candidates are required to go to a school that meets a certain diversity percentage, so that the student can see how it affects the learning environment. As engineering education majors, students have a lot of variety as to what they can observe; so far, engineering education students have observed physics, algebra, technology and Project Lead the Way courses.

Courses which include integrated service hours include:

Curriculum and Assessment	30 hours of field experience
*Integrated Mathematics Methods	30 hours of field experience
*Educational Psychology	30 hours of field experience
*Literacy Through the Content Area	30 hours of field experience

A total of 120 field experience hours are needed to complete the teacher education program, not including the hours achieved during both 5 day field experiences.

The courses indicated with an asterisk * are those for which students must be admitted to the Center for Teacher Education first. To be admitted to this program, students fill out paperwork, obtain recommendations from professors, advisors and the Dean's office and must have grades of C or better in all math courses, Writing Seminar, Culture and Schooling, Classroom Communication, 5 day 1 and Lifespan Development.

Engineering Education 1 and 2 offer the design of engineering curricula, policy as it pertains to incorporating engineering into K-12, and subjects from courses in typical education plans of study such as Technology in the Classroom and History of Mathematics. Topics from these courses are found on the certification exams, so this content is integrated into Engineering Education 1 and 2.

The senior year is also unique. Engineering Education students will complete an engineering senior design project, although they are expected to look at the project from its possible implementation in a high school classroom. They will also complete a full semester of student teaching. Since education students normally are prohibited from taking courses while student teaching, engineering education majors must complete the bulk of their senior design during the first semester, and work on implementation in their second semester. Note that "Leadership" is offered in conjunction with all student teaching, and is not considered as taking a class while student teaching.

One further difference is that these students take enough courses as part of their plan of study to obtain a minor in mathematics as part of their plan of study, so all should graduate with this minor.

The university education program was assessed for their National Council for Accreditation for Teacher Education (NCATE) accreditation during the first year of Engineering Education. The accreditation visit was incredibly successful, and very complimentary remarks were made regarding engineering education. The plan of study meets ABET accreditation requirements as specified for General Engineering and similar programs[6]. The program will be submitted for accreditation once there are graduates of the program (an accreditation requirement).

Extracurricular Activities

With the intense national interest in STEM education, students in this plan of study have a steady stream of opportunities. A student section of ASEE has been formed. Students have led two STEM days for a local K-12 district, demonstrating hands-on activities to students up to 6th grade. STEM At the Park was a public STEM workshop with students helping K-12 students build rubber band race cars. Students have had opportunities to help with teacher workshops held on campus and held in schools in the Dominican Republic.

Engineering Education students are welcomed into the engineering, math, AND education societies, including professional societies for disciplines within engineering (ASCE, ASME, IEEE) and Secondary Education Society, Mathematical Association of America, etc.

Students are advised to maintain a portfolio of their participation in these activities; upon graduation, they will certainly need to explain the significance of their degree.

Student Motivation

Motivation to study Engineering:

Among reports documenting research into student motivation to study engineering, the Center for Advancement of Engineering Education (CAEE)[7] reported that students were motivated to study engineering by (in order):

1. Intrinsic (psychological) factors
2. Intrinsic (behavioral) factors
3. Social good
4. Financial
5. Influence of mentors
6. Influence of parents

Further, students who were motivated to study engineering for their own enjoyment or intrinsic reward were found to be more likely to persist. These findings are supported by research from

Purdue University: studies have shown that including affective characteristics (motivation, perception of leadership ability for example) lead to a more effective prediction of student success (retention into the second year of study) than models solely based on cognitive variables (GPA, number of semesters of math, etc.)[8,9] Additional study from an American Society for Engineering Education (ASEE) committee[10] emphasized the importance of student motivation toward their success and is strongly linked to self-efficacy, the belief that the individual student can succeed at a specific task[11,12,13].

These findings indicate that students who may be more driven toward engineering for intrinsic factors and/or the desire to good for society do, in fact, select engineering for a field of study; that desire for future financial gain is typically not the primary motive of most incoming students.

Three of the original cohort of four students selecting Engineering Education as their major participated in an email survey consisting of open ended questions[14]. Among the findings were that the students who responded had planned to major in engineering while in high school. One said that he repeatedly heard the message that, because he was good at math and science, "I should be an engineer", a common message in K-12. Each of the three students said that they had an interest in teaching or working with children in some aspect, and each student cited their parents for influencing them toward engineering. While the sample size is too small to draw a general conclusion, the students who participated were interested in either teaching or engineering and had parental influence toward engineering.

Each student said that they selected Engineering Education because it brought their interests of teaching and engineering together. Further, each student said that the fact that the major was new and unique had no influence in their decision. The strength of the degree program with foundations soundly in both areas seems to be an important factor – more than simply the novelty of a new, unique or innovative degree program. While the sample size is small, it is rewarding to see students reporting that they selected the major on its merits rather than its novelty.

None of the students had a specific 5-year plan; not surprising, given that they were first-semester students at the time of the survey. Two students mentioned possibly plans to pursue a Master's Degree on their way to a Ph.D., where one said he may go into academia. Two mentioned a strong possibility of teaching in the K-12 environment. Two mentioned working as an engineer; it may be significant that this was not the first option mentioned either time. Time and graduate experiences will tell what 5-year plans may be realistic for graduates of this degree program.

Much of our existing data replies on conversations with students as they begin to formulate long term goals. One student's summation was typical of conversations we have had this year:

> "Where and what type of employment this might be is still unclear due to the foggy career options that this major entails."

Conclusion

The Bachelor of Science degree in Engineering Education offers an opportunity for graduates with an engineering degree to enter the classroom with the full training afforded through an education degree. The plan of study has strong elements of engineering, mathematics and education for a truly interdisciplinary educational experience, and has field service hours to help the student be certain of their future in front of a classroom. Students currently working through service hours have been very successful.

With an innovative plan of study, ample opportunities to lead and participate in extracurricular activities and opportunities to publish in and attend conferences, the expectation is for enrollment growth and dissemination.

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