
AC 2011-507: CERTIFICATE/CONCENTRATION IN ENGINEERING FOR P-12 EDUCATORS

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Certificate/Concentration in Engineering for P-12 Educators

The engineering community has called for the integration of engineering content into the P-12 curriculum. However, universities have been slow to offer engineering content courses and programs designed for students preparing for careers in education. While a number of workshops and summer academies exist, their focus is often on specific engineering activities for the classroom. As P-12 teachers tend to lack confidence in their knowledge of engineering and their ability to incorporate it into their teaching, programs which strive to give P-12 teachers a depth and breadth of engineering knowledge become more important. The CCLI project presented in this paper focuses on the creation of a minor in Engineering Education for undergraduate students majoring in Education. Preliminary results from the first six months of this project will be presented. Details on the courses encompassed by the minor, as well as the recruitment and retention plan for the minor are presented.

Introduction

In their review of the current state of P-12 Engineering Education¹, Brophy et al. list “teacher readiness and professional development” as the first major challenge to furthering P-12 engineering education. They also emphasize the need to focus on pre-service teacher education. Research by Yasar et al. has shown that while teachers are generally interested in using engineering and design processes in their classrooms, very few are confident doing so or have been trained in how to do so². Many universities have begun to offer continuing education engineering programs for teachers. (Some examples of this include: Stevens Institute of Technology’s “Center for Innovation in Engineering and Science Education” offers engineering workshops for teachers³, Purdue University’s INSPIRE Summer Academy⁴, and Worcester Polytechnic Institute’s PEE (Partnerships Implementing Engineering Education) program⁵. While all three of the above programs focus on training teachers in teaching engineering, none of them consists of formal university credit bearing courses. Instead they use methods such as intensive summer academies, short and long duration workshops, and weekly cohort meetings. Additionally, all three of these programs (and many like them) are particularly focused on teaching engineering curricula to in-service educators.

In 2010, Minnesota adopted new Academic Standards in Science focused on engineering. These new standards are intended to be embedded into other existing strands of the standards. Two of the new standards are included below to give a taste of what is being implemented.

Grade	Strand	Substrand	Standard	Code	Benchmark
2	The Nature of Science and Engineering	The Practice of Engineering	Engineering design is the process of identifying a problem and devising a product or process to solve the problem.	2.1.2.2.1	Identify a need or problem and construct an object that helps to meet the need or solve the problem. <i>For example:</i> Design and build a tool to show wind direction. <i>Another example:</i> Design a kite and identify the materials to use.
9 10 11 12	The Nature of Science and Engineering	The Practice of Engineering	Engineering is a way of addressing human needs by applying science concepts and mathematical techniques to develop new products, tools, processes and systems.	9.1.2.1.3	Explain and give examples of how, in the design of a device, engineers consider how it is to be manufactured, operated, maintained, replaced and disposed of.

Program Details

In response to the trends discussed above, the University of St. Thomas received a CCLI grant to create a minor in Engineering Education. (Note that at the time of the proposal it was being called a “concentration,” however it has been decided by the schools involved that the title “minor” is more appropriate.)

Courses required for an Undergraduate Minor in Engineering Education (total of 20 undergraduate credits):

- Fundamentals of Engineering (4 credits)
- Engineering Graphics and Design (4 credits)
- 8 credits of engineering and STEM electives
- Engineering in the P-12 Classroom (4 credits)

In parallel with the minor in Engineering Education that is intended for undergraduate Education majors, a graduate certificate in Engineering Education for current in-service teachers has been developed.

Courses required for a Graduate Certificate in Engineering Education (total of 12 graduate credits):

- Fundamentals of Engineering (3 credits)
- Engineering Graphics and Design (3 credits)
- 3 credits of engineering electives
- Engineering in the P-12 Classroom (3 credits)

The electives in both programs are intended to allow teachers to specialize in a specific area of engineering or broaden their exposure to engineering, math, science and technology. These electives would be selected under the advisement of the student's concentration co-advisors from the Schools of Engineering and Education. Students will be allowed to choose from existing engineering courses, as well as from a number of specialty engineering education courses that will be created as the program grows.

For the undergraduates, the following undergraduate engineering classes are recommended electives. Additionally, recognizing the important role that Physics plays in Engineering, undergraduate students are allowed to count 4 credits of Physics towards the minor.

- Digital Design (ENGR 230) (*This course has no prerequisites.*)
- Engineering and the Environment (ENGR123) (*This course has no prerequisites.*)
- Manufacturing Processes (ENGR 371) (*This course has no prerequisites.*)
- Engineering Materials (ENGR 361) (*This course has a Chemistry prerequisite.*)
- Engineering Mechanics I (ENGR 220) (*This course has a Physics prerequisite.*)
- Introduction to Electronics (ENGR 350) (*This course has a Physics prerequisite.*)
- Thermodynamics (ENGR 381) (*This course has a Chemistry prerequisite.*)
- Astronomy (PHYS 104) (*This course has no prerequisites.*)
- Musical Acoustics (PHYS 105) (*This course has no prerequisites.*)
- General Physics I (PHYS 109) (*This course has no prerequisites.*)
- Classical Physics I (PHYS 111) (*This course has no prerequisites.*)

Note that some of these classes have prerequisites, but that the prerequisites are courses that the students in the minor may already have, depending on their majors or co-major. The graduate students in the certificate program can choose from existing graduate engineering classes, with the guidance of their certificate advisor.

Course Descriptions

Below are descriptions for the Engineering Education minor's required courses.

ENGR 130: Fundamentals of Engineering for Educators
(4 undergraduate credits)

This is a one-semester survey of engineering topics. Topics will span machine design, manufacturing, thermodynamics, electronics, computer programming, and chemical engineering. The course will have weekly lab sessions which will allow students to apply what they are learning from lectures in a hands-on setting. Emphasis will be placed on how the material is used by practitioners. Numerous examples will be given of how this material can be presented in a way that meets Minnesota education standards. Each topic unit will include a component dedicated to the historic and current relevance of the concepts and skills presented. Whenever appropriate, and feasible, guest lectures and field trips will be arranged.

ENGR 130 is a new course designed specifically for the Engineering Education minor. It is co-listed with an analogous class (ETLS530) which is the graduate class for in-service teachers. The two classes are taught concurrently in the same classroom so that the pre-service students can learn from the in-service teachers.

ENGR 171: Engineering Design and Graphics
(4 undergraduate credits)

Students will learn to read blueprints and working drawings and become familiar with computer-aided-design (CAD) terminology and technology. Topics cover the elements of drafting including: the use of CAD modern software based on solid modeling; principles of projection; and introductory methods of representation and constructive geometry, working drawings, conventions and standards.

ENGR171 is an existing course required of Mechanical Engineering students. As the Engineering Education program grows, it has been proposed that a separate lab section intended for Education students could be developed. One reason for this is that the use of a freeware CAD program, such as Google Sketchup, would be beneficial for educators. ENGR171 currently uses SolidWorks, which, while available in some K-12 schools, cannot be assumed to be available at all schools. Additionally, as Google Sketchup is free (for the most basic package), K-12 students with access to a computer could use it outside of class hours. This course is the undergraduate version of ETLS 531, a required course for the graduate certificate in Engineering Education.

EDU 327: Engineering in the P-12 Classroom
(4 undergraduate credits)

This course will focus on an overview of current P-12 engineering education programs; exploration of pedagogy and content; links to national and State Academic Standards;

and a survey of assessment mechanisms that evaluate impact of classroom initiatives. A variety of delivery modes will be used to introduce students to methods and to educators who have successfully introduced engineering into a wide variety of classes across several disciplines. Engineering resources for teachers will be presented and discussed. A final project is required, in which students create a unit or module focused on a hands-on engineering activity for P-12 students in their licensure area.

EDU 327 is a new course designed specifically for the Engineering Education minor. The analogous class in the graduate certificate is TEGR 528. The two classes are currently taught concurrently in the same classroom, with differentiated assignments, so that the pre-service students can learn from the in-service teachers.

Project Team

This project is a collaboration between the University of St. Thomas' schools of Engineering and Education. Faculty from both departments are involved with the development of the courses for this program. The assessment for this project is being coordinated and executed by researchers from Purdue's INSPIRE (Institute for P-12 Engineering Research and Learning). An educator from the St. Paul Public School district is serving as the educator consultant.

Project Timeline

The grant for this CCLI project was awarded effective July 1, 2010. The summer of 2010 was then spent working on the development of the new courses and submission of the minor proposal.

In the fall of 2010, EDU327 was approved as a new course by the School of Education's curriculum committee and ENGR130 was approved by the School of Engineering curriculum committee. Upon the School of Engineering's approval of the minor, the proposal was sent to the university's Undergraduate Curriculum Committee, where it was approved and then sent to the university's full faculty for consent. At the completion of this process, the minor was officially accepted.

In parallel to this process for the minor, the Engineering Education graduate certificate was approved by the curriculum committees of the School of Education and the School of Engineering, as well as the university's Graduate Curriculum Committee. The final step before official announcement of the certificate is approval from Minnesota's Higher Learning Commission. Both the minor and the certificate are on track to be officially announced, and entered into the university's course catalog, in the spring of 2011.

The first section of “Fundamentals of Engineering for Educators” (combined graduate and undergraduate) was offered in Fall 2010. The class had an enrollment of 2 undergraduate students (pre-service teachers) and 13 graduate students (in-service teachers).

“Engineering in the P-12 Classroom” was to be offered for the first time in the Spring of 2011, primarily for graduate students. A section of “Fundamentals of Engineering Education for Educators” for undergraduate Education majors will also be offered in the Spring of 2011.

To accommodate undergraduate students who are busy with student teaching during the semester, as well as in-service teachers who are teaching during the semester, we will be offering both “Fundamentals of Engineering for Educators and Engineering in the P-12 Classroom” in an intensive compressed format in the summer of 2011. In this format, students will attend the course for 40 hours in a weeklong format. This will be followed by approximately 8 weeks during which the students will work on assignments based on the content from the intensive week. This work will be submitted electronically (or via postal mail), and feedback will be given to the students. Finally, the students and instructor will reconvene after this period for final project presentations and, if appropriate, an in-class final examination.

Program Assessment

A variety of methods will be used to assess 1) the undergraduate engineering courses for educators that we develop; 2) student learning outcomes related to engineering content and design pedagogy for pre-service educators; and 3) articulation of effective components that result from this project. Formal external program assessment is being done by researchers from Purdue’s INSPIRE institute.

At this time, a formative assessment for the first course offering, the combined undergraduate/graduate Fall 2010 section of “Fundamentals of Engineering for Educators,” has been done. This was carried out by an external assessor from the Science Museum of Minnesota. More details of this assessment can be found in a paper focusing on the course,⁶ however the overall findings were that the course was well received by both the undergraduate and graduate participants, but that there were a number of improvements that could be made.

Project Challenges

Even at this early stage in the project, we can identify some of the challenges that will be encountered as we move forward. The first of these is recruitment. Currently, undergraduates majoring in Elementary Education at the University of St. Thomas are required to complete a second major. To the best knowledge of the authors, there has never been an Education student who has chosen Engineering as their second major. Thus, students pursuing the minor, at this time, would need to take it on top of their other two majors. Under this system, it is more likely that the students would take one or two classes from the Engineering Education minor program, rather than the whole minor. Likely candidates for the Engineering Education minor are students majoring in Science and Mathematics for Elementary Education (SMEE), a co-major that is the

only exception to the double major policy stated above. A student majoring in SMEE can, with permission, incorporate three of the 5 Engineering Education minor courses into the SMEE major. This would mean that only two additional courses would be needed to complete the minor. It should be noted that both of the undergraduate students who enrolled in the Fall of 2010 “Fundamentals of Engineering for Educators” course were SMEE students. The schools of Engineering and Education are continuing to work together to brainstorm, and hopefully implement, ways to get more Education majors involved with the Engineering Education minor.

A second challenge, and one raised by the reviewers of our CCLI proposal, is whether education students will be comfortable in traditional engineering classes where the other students are engineering majors. This is the case in ENGR171 and in the electives. We are cognizant of the possible challenges raised by this and will be making every effort to ensure that the education students have appropriate resources and support as they enter, and take, these courses.

Conclusion

The University of St. Thomas has launched two new Engineering Education programs, one undergraduate and one graduate, for students majoring in Education. The development of these programs, still in their early stages, is a collaboration between faculty from the Schools of Engineering and Education.

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