5th Year Master's Degree Program for Engineers: Preparing the Next Generation of K-12 Technology, Engineering and Design Education Teachers (Work in Progress)

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Abstract

A new non-thesis, project-based 5th year Master's degree program in Technology Education has been created at North Carolina State University in response to a growing state and national need for more qualified Technology, Engineering and Design Education (TDE) teachers in K-12. This unique program is a collaborative effort between the Colleges of Education (CED) and Engineering (COE) and targets undergraduate students in COE that have an interest in teaching at the K-12 level. As a part of the program, students first earn a Bachelor of Science degree in an engineering discipline and then complete an additional year of pedagogy-focused coursework and a student teaching experience in CED to earn the Master of Science in Technology Education and a license to teach TDE in middle and high school. The purpose of this project was to develop a program that would best prepare and train pre-service teachers to translate their technical knowledge of engineering to middle and high school audiences. This paper will describe the program and the rationale for its development and conclude with a summary of potential programmatic impacts and future research opportunities.

Introduction

It has been widely reported that the U.S. must produce more highly skilled individuals in the science, technology, engineering and mathematics (STEM) fields in order to maintain its historical competitive advantage in these areas. According to an executive report issued by the President's Council of Advisors on Science and Technology (PCAST), the U.S. will need to increase the number of students who receive undergraduate STEM degrees by about 34% annually over current rates to meet future workforce demands[1]. If this goal is to be realized, more effort must be directed towards strengthening STEM education in K-12. The U.S. lags behind other nations in STEM education at both the elementary and secondary levels, with U.S. students performing consistently lower in science and mathematics than their international counterparts[2]. In recognizing the severity of this issue, the President has committed federal funds to assist in revamping K-20 STEM education with a goal of providing funding and support to prepare 100,000 new K-12 STEM teachers by 2020[3].

Early exposure to STEM disciplines, particularly engineering, is critical to our ability to attract students to the field. It has been observed that unless a student has a parent or relative who is an engineer, it is unlikely that they will be exposed to a role model outside the school who can introduce them to the interesting aspects and challenges of engineering[4]. According to Kimmel et al.[5], most middle and high school students and many of their teachers still do not have a positive attitude towards engineering or do not really know what engineers do. Moreover, many secondary school students lack an understanding of the enormous impact that engineers have on society and how almost everything they use in their daily lives is dependent on various forms of engineering[5,6]. This fact, coupled with a declining interest in math and science among American children has resulted in K-12 students shying away from engineering as a career choice[4,7]. One of the keys to reversing this trend is to prepare elementary and secondary teachers to introduce engineering and technology principles into the classroom through various training and support mechanisms. Unfortunately, most teachers' collegiate experiences do not include the study of engineering principles[4]. Teachers are typically uncomfortable teaching content they do not understand and thus, will tend to shy away from such content for fear of not being able to answer students' questions[8]. However, teachers that are trained in basic engineering principles and how to effectively teach them are comfortable sharing this knowledge with their students and therefore, are able to present engineering in a more positive light[4]. Research has shown that teachers have a significant influence on student performance and achievement outcomes[9,10]. In a study utilizing the Longitudinal Survey of American Youth to determine the effects of teacher knowledge in mathematics and science on student achievement, Monk[10] found that how much a teacher knows about the subject matter has a positive effect on students' learning gains. In addition, he observed that undertaking pedagogy coursework contributed positively to student learning and in some instances had more powerful effects than additional preparation in the content area. Therefore, it was concluded that a good grasp of one's subject area is necessary but not sufficient for effective teaching. Similar results were reported by Hill et al.[11] when exploring the effects of teachers' mathematical knowledge on first and third grade students' mathematics achievement.

There has been a greater emphasis on the "E" in K-12 STEM education over the past several years[4], with increasing numbers of elementary, middle and high schools incorporating engineering concepts into their classrooms. The advent of the Next Generation Science Standards (NGSS), which include an engineering design component, has further encouraged the integration of engineering principles into the K-12 curriculum. Some would argue that individuals that have earned an engineering degree are in the strongest position to accurately introduce K-12 students to engineering and encourage them to enter the field[12]. Students that are able to successfully complete an engineering degree from an accredited engineering program possess the content knowledge to teach STEM subjects at the K-12 level and can help to remove the misconceptions in the minds of K-12 students about what engineers actually do. However, what these students typically lack is pedagogical content knowledge (PCK), a concept that encompasses not only knowledge of one's subject matter, but also knowledge of ways to represent and formulate the subject to make it comprehensible to others[13].

Much of the literature regarding teacher PCK and its implications in teaching and learning in K-12 has focused on the fields of science, mathematics and technology education. Numerous articles have been published in recent years investigating the relationship between teacher PCK and student achievement outcomes in science, mathematics and technology[11,14,15,16,17]. Many of those studies have aimed to shed light not only on the influence of PCK on student learning, but on the creation of effective strategies for developing PCK in pre-service teachers. In a study by Nilsson[16] that explored the development of student-teachers' PCK during pre-service education, it was observed that engaging science teachers in projects with substantive focus on reflection on their own teaching is important in helping to change their thinking about science teaching and learning and to initiate the development of PCK. Furthermore, Nilsson[16] found that team teaching and videotaped lessons were two useful ways of promoting reflection of their teaching, and subsequently developing their PCK. Similarly, in a study investigating two components of PCK: (i) knowledge of students' understanding, conceptions and misconceptions of topics, and (ii) knowledge of strategies and representations for teaching particular topics, it was concluded that engaging in serious reflection on how to use the knowledge of student misconceptions in physics was needed to guide transformation of the content in planning for instruction[18]. Baumert et al.[19] attempted to answer questions such as: what kind of subject matter knowledge do teachers need to be well prepared for their instructional tasks and to what degree does their mastery of the content influence their instructional repertoire? In agreement with other studies, a positive effect of teacher PCK on students' learning gains mediated by the provision of cognitive activation and individual learning support was shown[19]. Another important tentative conclusion drawn from that study was that teacher education programs that compromise on subject matter training do so at the detriment of PCK development and subsequent instructional quality and student progress.

The types of studies mentioned above are helping to shape teacher professional development activities in mathematics and science education. In contrast, there have been little to no studies regarding PCK development of secondary teachers of engineering. After a review of the literature, we found just one study that evaluated post-secondary engineering teachers' PCK. In that study, the authors compared the conceptions maintained by teachers with those of their students on moment of forces, which is one of the most difficult concepts for first year students in civil engineering to grasp[20]. They concluded that teachers' lack of knowledge of their students' conceptions suggested that there needed to be greater emphasis on this aspect in their teacher education courses. Similar studies are needed to evaluate the impact of teacher PCK on student academic achievement and interest in engineering[20]. Providing students in the proposed 5th year Master's program with the pedagogical knowledge to accompany their existing engineering knowledge could create powerful ambassadors for engineering and STEM careers in the K-12 classroom.

The objective of this ongoing project is to develop a Master's level program in Technology Education that can be completed in one year and prepares engineering students with the PCK necessary to effectively translate their fundamental knowledge of engineering to middle and high school audiences.

Program Description

This unique non-thesis, project-based 5th year Master's program in Technology Education is a collaborative effort between the College of Education (CED) and the College of Engineering (COE) and targets COE undergraduates that have an interest in teaching at the K-12 level. As a part of the program, students first earn a B.S. degree in an engineering discipline and then complete an additional year of pedagogy-focused coursework and a student teaching experience in CED to earn the M.S. in Technology Education and a license to teach TDE in middle and high school. The training provided by this program will prepare pre-service teachers to implement technology and engineering design principles outlined in the NGSS.

The program consists of a total of 36 credit hours, including 15 credits of core education/pedagogy courses, 15 credits of Technology Education courses and 6 credit hours of a special project that will be administered jointly by faculty in CED and COE (Table 1). The requirement of an engineering education-based project in lieu of the thesis makes it possible for students to complete the degree within one year.

Table 1. Plan of Study

Semester (Credit Hours)	**Course (Credit Hours)**
Summer Session I, II (8)	Summer I: TED 530: Foundations of Teaching Technology (3) TED 692: Research Project in Technology Education (1) Summer II: ED 508: Exploring Diversity in Classroom and Community (3) ED 570: Classroom Action Research (1)
Fall (14)	ED 571: Inquiry and Professional Development (1) ED 507: Principles of Developing and Interpreting Assessment (2) ED 579: Organization and Behavioral Management of Inclusive Classrooms (3) TED 558: Teaching Creative Problem Solving (3) TED 552: Curricula for Emerging Technologies (3) TED 692: Research Project in Technology Education (2)
Spring (14)	ED 572: Teacher Leadership (1) ED 569: Teaching Internship (4) TED 555: Developing and Implementing Technology Education (3) TED 556: Lab Management (3) TED 692: Research Project in Technology Education (3)

Engineering Student Interest in the Program

Undergraduate students enrolled in COE were surveyed to determine their level of interest in such a program and there was an overwhelmingly positive response. Of the 1465 students that responded to the survey, nearly half of them indicated that they were interested in teaching in K-12 (Fig. 1). Furthermore, about 80% of those students interested in teaching also responded that they would be willing to complete an additional year of coursework to obtain the M.S. degree and teacher licensure. When asked to indicate the areas they would be most interested in receiving a teaching license, TDE received 84% of the responses (Fig. 1).

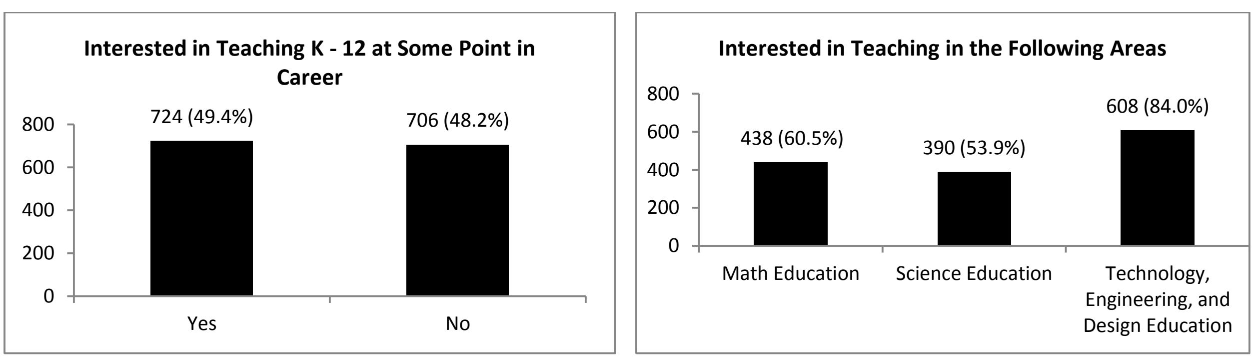

Figure 1. College of Engineering Undergraduate Student Survey

What is Unique About this Licensure Program?

Collaboration between the Colleges of Education and Engineering

The most unique aspect of this 5th year Master's program is the full collaboration and articulation agreement between the College of Engineering and the College of Education. This type of a collaboration is very timely given that research suggests that schools of engineering and education must work as a team to truly integrate technology and engineering into the K-12 core curriculum so that students understand and are prepared for careers in engineering[4,5]. The partnership between the two colleges will allow students to fully integrate their content specific knowledge of engineering with pedagogical knowledge acquired from coursework in CED through the completion of a six credit hour engineering education-based project. As a part of the project, students will develop several teaching artifacts related to an engineering topic and/or concept of their choosing to demonstrate their proficiency as a teacher. Those artifacts will include lesson plans, videos of themselves implementing the lesson plan during the student teaching experience and narratives related to instruction, planning and assessment. These are required for existing accreditation processes associated with Colleges of Education and contribute to a student's understanding of action research to be used in the classroom. Students will work closely with COE and CED faculty to select the engineering topic on which the lessons will be developed and taught.

One-year M.S. Degree Program

There are numerous licensure programs around the country that allow students that do not have a background in education to obtain a license to teach. However, there are very few programs that can be completed within one year. Unlike traditional 5th year Master's programs, this program requires completion of an engineering degree prior to being admitted into the program, i.e., no courses can be taken in fulfillment of requirements towards the graduate degree until a student has earned the bachelor's degree. In addition, most graduate level teacher education programs offer a Master of Arts in Teaching (MAT) rather than the Master of Science degree. The M.S. degree will allow students to have some research and content-based courses, all at the graduate level (not currently required by MAT programs), thereby preparing students for community college instruction as well. This new 5th year Master's program in Technology Education will be a full time, rigorous one year program where students begin as a cohort in the summer immediately following completion of the bachelor's degree and concludes in the spring semester of the following year. The majority of the courses that students will take will be face-to-face on campus as opposed to other one year MAT programs that primarily consist of online courses. This on-campus environment will allow for greater interaction between students and faculty from both colleges. The one year timeframe coupled with the M.S. degree offering and partnership between the two colleges is extremely attractive to engineering students and will be critical to our ability to recruit students to the program.

Summary and Future Outlook

The current shortage of students in the STEM pipeline is hampering our ability to meet national demand for STEM talent. This new 5th year M.S. program in Technology Education has been designed to address this issue by training engineering students to teach TDE at the secondary level, thereby potentially exposing more students to STEM fields and strengthening the quality of K-12 STEM education. Students in this program will have the added benefit of a second career choice in the future and the ability to use the degree in other states as a result of the reciprocity agreement between states. The first cohort of students is expected to begin the Master's program in the summer of 2016. We are anticipating an initial cohort of approximately 10-12 students with a goal of expanding the program in the coming years. As the first cohort progresses through the curriculum, we will remain reflective throughout the process and make meaningful changes to improve the student learning experience. We strive to develop a robust assessment plan to assess the impact of this program on pre-service teacher preparedness.

Looking ahead, this type of teacher education program that targets engineering students could lead to some potentially impactful scholarly research. For example, there are opportunities to investigate the effect of teacher PCK on student performance and achievement in engineering at the K-12 level. There's also a need to explore the relationship between teacher PCK and K-12 students' interest levels in engineering careers. Moreover, evaluation of this type of a program could generate best practices for developing PCK in secondary engineering teachers. Overall, this Master's degree program has the potential to increase the number of qualified Technology, Engineering and Design Education teachers in the state of North Carolina, and is a great example of how two colleges can work together to find a solution for societal needs.

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