ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37946

Development of a Hybrid Community of Practice Course Model to Prepare Pre-Service Teachers to Teach Engineering in K-12 (Work in Progress)

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I have a background in chemical engineering, getting my Bachelor's in 2021 in this area. I am currently pursuing my Master's in Chemical Engineering, as well as an Engineering Education Graduate Certificate. I have done past research in engineering education, working with how the COVID-19 pandemic affected engineering students. My current research looks at how perceptions of engineering affect pre-service teachers' self-efficacy at teaching engineering.

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Background and Motivation:

Providing K-12 students with the opportunity to engage in engineering practices is critical to increase engineering literacy, diversify the engineering workforce, and provide the skills and encouragement necessary for students to pursue careers in engineering [1]. The need to include engineering in the K-12 classroom is also heavily emphasized in the *Next Generation Science Standards*, as well as the standards of many states [2]. Many schools are attempting to meet these goals both by incorporating engineering into the existing mathematics and science curriculum and developing standalone engineering courses, which were offered by 46% of high schools who responded to a 2018 survey [3]. Achieving these goals, however, requires K-12 teachers that are both knowledgeable about engineering and confident in their ability to teach engineering concepts. To teach engineering effectively, it is critical that teachers understand what engineering is, how engineers perform their work, and the relationships between engineering and other fields such as science and mathematics [4].

Although engineering is becoming increasingly important in K-12 education, previous research has demonstrated that, similar to the general population, K-12 teachers typically hold inaccurate perceptions of engineering, which affects their ability to provide students with relevant engineering experiences. In particular, teachers have been shown to often confuse the work of engineers with that of automotive mechanics or construction workers or to assume that engineering is only for "super smart" students who are naturally gifted or who come from higher socioeconomic backgrounds [4-6]. Several studies have used the "Draw an Engineer Test (DAET)" to explore the preconceived ideas that both students and teachers have about engineers [7]. The drawings of K-12 teachers revealed misconceptions about engineers that were also present in the drawings of children, indicating that many teachers, even teachers who are currently teaching engineering, do not truly understand the nature of engineering work and have stereotypical attitudes about who is qualified to be an engineer. For example, most images drawn by both teachers and students primarily included white males working alone and people building or fixing things with tools [4-8]. This indicates that both teachers and students hold stereotypical attitudes about what engineers do and who is qualified to be an engineer.

These inaccurate perceptions of engineering among K-12 teachers are likely to impact their students' perceptions of engineering and to influence the way that teachers introduce engineering practices and make connections between engineering and other STEM disciplines [4]. One reason that teachers may hold these inaccurate perceptions of engineering is because they have little prior experience with engineering or training in engineering education. According to the National Principal and Teacher Survey, most teachers who are currently teaching standalone engineering courses are certified to teach mathematics or science, while less than half are certified to teach engineering and less than 20% have a major or minor in engineering or an engineering-related discipline [9]. Furthermore, the 2018 National Survey of Science and Mathematics Educators reported that only 13% of high school science teachers had taken at least one course in engineering, and among elementary and middle school science teachers, only 3 and 10%, respectively, had taken at least one engineering course [3].

Engineering teaching self-efficacy, which is defined as teachers' "personal belief in their ability to positively affect students' learning of engineering" [10,11], also affects the ability of teachers to engage students effectively. Teacher self-efficacy has been shown to not only influence teachers' willingness to engage with a particular topic, but also to have a significant influence on the motivation and achievement of their students [12]. Research also indicates that high-efficacy teachers exert more effort and utilize more effective instructional strategies than low-efficacy teachers [13]. The Teaching Engineering Self-Efficacy Scale (TESS) has been used to demonstrate that current K-12 teachers typically have a low self-efficacy with teaching engineering [10,11,14].

Taken together, this research indicates that there is a critical need to provide engineering education training to pre-service teachers, especially those mathematics and science teachers who are most likely to be teaching standalone engineering courses and other related courses. Although there are some colleges and universities that currently provide training to prepare pre-service teachers to teach engineering, many still do not. One reason for the absence of engineering education courses in pre-service teacher training is that most colleges of education do not have any engineers among their faculty, and the faculty members that are responsible for preparing pre-service teachers rarely have any experience with engineering themselves [1].

One promising model for pre-service teacher training that has been explored at a few post-secondary institutions involves engineering and education departments partnering to provide pre-service teachers with more authentic engineering experiences. For example, at North Carolina State University, students pursuing a B.S. in elementary education must complete a course in engineering design methods that is taught by faculty from the college of engineering [15]. The University of South Florida offers a course in STEM issues for pre-service middle school math and science teachers that is co-taught by faculty from engineering and education and teachers in a local school district [16], while at Iowa State University, education and engineering faculty jointly teach a class for education majors called Toying with Technology [17], and Hofstra University offers a unique K-5 STEM Education major that includes 4 required engineering education courses that are taught by faculty from the college of engineering [18]. Although all of these programs are promising, the effectiveness of this model of engineering teacher training has not yet been systematically investigated.

Course Description:

At the University of Tennessee Knoxville (UTK), the VolsTeach program, is a permanent degree program that allows students to simultaneously complete a degree in a science or mathematics field while also obtaining teacher licensure. Key coursework in the VolsTeach program integrates mathematics and science content and clinical experiences. We have created an innovative course model, in which two courses, one designed to introduce VolsTeach students to STEM teaching, (*TPTE 115: Intro to STEM Teaching*) and one designed as a service-learning course for engineering undergraduate students (*EF 327: Engineering Design in K-12 Education*), are taught together by a team of instructors from both the Engineering Fundamentals (EF) division and the department of theory and practice in teacher education (TPTE).

In this combined course, students learn about the field of engineering and how it can be incorporated into K-12 STEM teaching, as well as learning about how to teach effectively and how to create instructional materials. They complete a series of service-learning projects that include working directly with K-12 students and families at community outreach events and developing videos and lesson plans that can be used to teach engineering in K-12 classrooms. Existing partnerships with Knox County Schools allow students enrolled in the course to work directly with in-service teachers to develop authentic, engaging engineering projects and lessons that address state and national standards and represent the different disciplines of engineering. All materials developed as part of this course are freely shared with local teachers and the public. Examples of the projects completed by students in the course are listed in Table 1.

Table 1: Example projects completed by students in EF327/TPTE115

Project	**Description**	**Examples**
Mini-Teach	Students choose a topic and have 5 minutes to teach the class about their chosen topic. Each student is provided with feedback from peers and instructors.	(1) An explanation of computer sorting algorithms (2) An overview of the engineering design process
Community Outreach	Students work in small groups to select engineering-focused activities to use to teach K-12 students about engineering in various community outreach events (STEM family nights, after-school clubs, campus visits, etc.). Then, students perform these activities with K-12 students during at least 2 live, in-person events.	(1) Think Like a Computer activity developed for an elementary level after-school engineering club (2) Captain Chaos activity designed to teach high school students about the engineering design process and used at Big Orange STEM Saturday
STEM Spark Video	Students develop a short video designed to teach K-12 students a STEM concept. These videos are disseminated to local schools and the public through the East TN STEM Hub.	(1) Balancing popsicle sticks on your finger by altering their center of mass (2) Electrostatic butterflies activity to learn about static electricity
K-12 Lesson Plan	Students develop a series of engineering-focused lesson plans, which are distributed to teachers in Knox county to use in math, science, and engineering courses, as well as in future community outreach events.	"Engineering in Reverse" - students learn about the engineering design process by taking apart a small flashlight and developing ways to improve it. This activity includes lesson plans for multiple days, including a lesson on using a multi-criteria decision-making model to evaluate the best potential solutions.

Research Plan:

The primary goal of this research project is to examine how pre-service K-12 teachers' perceptions of engineering and self-efficacy with teaching engineering develop within the context of a hybrid community of practice. A community of practice is defined as a "group of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly [2, 19]." Because the pre-service teachers and engineering students who are participating in the course have very different personal experiences and background knowledge, this course will facilitate the development of a community of practice that is also a hybrid space where students can draw on their own personal experiences and backgrounds to engage in novel and creative ways with each other [20,21]. Participation in such hybrid communities of practices has been demonstrated to facilitate identity development and self-efficacy growth [21,22]. The results of this research will provide actionable information that can be used to create or refine engineering education courses designed to prepare pre-service teachers to teach engineering in K-12.

To examine how participation in this hybrid community of practice impacts pre-service teachers' perceptions of engineering and self-efficacy with teaching engineering, a sequential explanatory mixed-methods design will be utilized [23]. We have developed a survey by adapting sections of several previously published surveys, including the Teaching Engineering Self-Efficacy Survey (TESS) [10,11], the Design, Engineering and Technology Survey (DET) [24], and a survey described in a 2008 National Academy of Engineering (NAE) report that was designed to evaluate perceptions of engineering in the general public [25]. This survey will be administered to course participants in EF 327/TPTE 115 at the beginning and end of the semester. Participants will also complete reflective journals (see Table 2) throughout the course and participate in semi-structured interviews at the end of the course.

Table 2: Example Reflective Journal Prompts

Reflective Journal Questions
How do you view math, engineering, or science education differently from when you began this class?
Has participating in this class changed your understanding of how to teach engineering? How?
How has participating in this class impacted your confidence in your ability to teach math, science, or engineering in the future?
What did you learn about yourself in this course?
How would you describe engineering to a [elementary/middle/high] school student?

Future Plans:

The EF327/TPTE 115 course was developed during the Fall 2022 semester and was taught for the first time during the Spring 2022 semester. The survey and interview protocol were also developed during 2021 and pilot data was collected from students during Spring 2022. We plan to begin collecting data in the Fall 2022 semester and to collect quantitative and qualitative data

for at least three semesters (Fall 2022, Spring 2023, Fall 2023). We anticipate enrolling approximately 10 participants each semester for a total of 30 students.

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