Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #49120

BOARD # 429: Pre-Service Teachers' Engineering Teaching Self-Efficacy Enhanced By Participation in a Hybrid Community of Practice

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NSF-RIEF: Pre-Service Teachers' Engineering Teaching Self-Efficacy Enhanced By Participation in a Hybrid Community of Practice

Abstract

The first exposure to engineering that most K-12 students have is in the classroom. However, K-12 teachers typically have limited or no experience with engineering or engineering education. As a result, they commonly hold many misconceptions about engineering as a field and a low self-efficacy with teaching engineering, which makes them reluctant to include engineering in the curriculum at more than a very superficial level. This leads to a lack of interest in engineering among K-12 students. Consequently, there is an urgent and critical need to provide more exposure to engineering and training in how to teach engineering to both pre-service and in-service K-12 teachers.

In this study, a new course was created in which pre-service teachers and engineering undergraduate students collaborated to develop engineering-focused activities for use in K-12 classrooms and support local K-12 schools and communities by facilitating after-school engineering clubs and family STEM nights. This course intentionally created a hybrid community of practice, and this project explored the ways in which participation in this hybrid community of practice impacted pre-service teachers' perceptions of engineering and engineering teaching self-efficacy. To assess this impact, a survey designed to measure engineering teaching self-efficacy was completed by pre-service teachers at the beginning and end of the course. In addition, pre-service teachers also completed reflective journals throughout the course in which they were asked to reflect on how specific aspects of the course impacted their understanding of the nature of engineering and confidence in their ability to teach engineering. All reflective journals were collected and analyzed qualitatively using an open coding method to identify common themes in responses.

Based on quantitative survey results, the self-efficacy of pre-service teachers with teaching engineering increased as a result of participating in this course. Furthermore, qualitative analysis of reflective journal entries revealed that pre-service teachers felt more confident in their ability to teach engineering after completing the course, with many indicating that the course increased both their self-efficacy and understanding of engineering as a field. Participants also stated that they felt more prepared to talk about engineering with K-12 students, and that they understood the importance of incorporating engineering into their future courses.

Background and Motivation

Engineering provides a unique opportunity for K-12 students to develop problem-solving skills, utilize creativity, and learn about potential career opportunities [1,2]. Consequently, the need to engage K-12 students in authentic engineering practices is well recognized [3,4]. However, barriers to teaching engineering effectively in K-12 classrooms still exist. In particular, one barrier is the lack of experience with engineering and engineering education among K-12 teachers. Less than 13% of high school science teachers have taken at least one course in engineering, and among elementary teachers, that drops to 3%. Even teachers of high-school level engineering courses do not commonly have a background in engineering, with only 20% possessing either a major or a minor in an engineering discipline [3,5].

To effectively teach engineering content, it is critical that teachers first understand what engineering is, how engineers perform their work, and the relationships between engineering and other STEM fields. However, because many K-12 teachers do not have personal experience with engineering or training in how to teach engineering, they often hold inaccurate perceptions of engineers and engineering. This impacts their self-efficacy with teaching engineering as well as their willingness to attempt to incorporate engineering practices into their classrooms [6-8]. Engineering teaching self-efficacy, which is defined as teachers' "personal belief in their ability to positively affect students' learning of engineering" [7,8], directly affects the ability of teachers to engage students in engineering practices. The Teaching Engineering Self-Efficacy Scale (TESS), a survey developed by Yoon and Strobel to measure the self-efficacy of K-12 teachers, has demonstrated that the engineering teaching self-efficacy of current K-12 teachers is typically quite low [7,8].

To provide pre-service STEM teachers with exposure to engineering and engineering education, we developed a new service-learning course model in which pre-service STEM teachers and engineering undergraduate students collaboratively learn about engineering and STEM education and engage in service learning in the local community and in K-12 schools. The course is structured to facilitate the development of a hybrid community of practice, and this research project explores the ways in which participation in this course impacts pre-service teachers' perceptions of engineering and engineering teaching self-efficacy.

Overview of Course

At the University of Tennessee, the Vols Teach program was created to provide a pathway for undergraduate students pursuing a science, mathematics, or engineering degree to simultaneously obtain teacher licensure. Students enrolled in this program take an introductory course (*TPTE 115: Intro to STEM Teaching*) that includes instruction on STEM pedagogy, classroom observations, and service-learning in local K-12 schools. To provide the pre-service teachers enrolled in this course with more exposure to engineering education, we combined this course with another existing course (*EF 327: Engineering Design in K-12 Education*). EF 327 was originally designed as a service-learning course for engineering undergraduate students in which students developed engineering-focused lesson plans and engaged in service learning by facilitating after-school engineering clubs and family STEM nights at local schools. The new

course (*TPTE 115/EF 327*) was co-taught by a team of instructors from both the Engineering Fundamentals (EF) program and the department of theory and practice in teacher education (TPTE). In this new combined course, both groups of students learn about STEM pedagogy and how to incorporate engineering in both K-12 classrooms and informal educational spaces. They also collaborate with each other to complete a series of service-learning projects that include working directly with K-12 students and families at community outreach events and developing STEM and engineering-focused videos and lesson plans that are shared with local K-12 teachers and used in future outreach events. All materials developed as part of this course are freely shared with local teachers and the public. Example course assignments are provided in Table 1.

Table 1: Example projects completed by students in EF327/TPTE115 [adapted from 9]

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 {Name Redacted}	(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 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.

Methods

A modified form of the TESS survey was administered to pre-service teachers enrolled in TPTE 115 at the beginning and end of the course to assess the impact of participation on their engineering teaching self-efficacy. We included questions from the TESS that were designed to assess participants' self-efficacy with teaching engineering using 2 constructs: content knowledge self-efficacy and engagement self-efficacy. Content knowledge self-efficacy measured participants' self-efficacy as it relates to knowledge about engineering, while engagement self-efficacy measured participants self-efficacy with engaging students in engineering practices. The course was taught for 4 semesters (Fall 2022, Spring 2023, Fall 2023, Spring 2024), and a total of 42 students completed both surveys.

Students also completed written reflections at the end of the course in which they discussed their perceptions of engineering and engineers, self-efficacy with teaching engineering, and the impact of participating in the class on both their perceptions and self-efficacy. An open-coding approach was used to analyze these reflections. Each student was assigned a pseudonym, and two members of the research team independently analyzed the anonymized reflections. Each researcher identified relevant segments of text and identified themes in the writing related to the pre-service teachers' perceptions of engineering and engineering teaching self-efficacy.

Results and Discussion

After completing the course, pre-service teachers exhibited modest gains in both engineering content knowledge self-efficacy and engineering engagement self-efficacy, as assessed by the TESS survey. Engineering content knowledge self-efficacy increased from a mean of 2.38 at the beginning of the course to 2.10 at the end of the course, while engineering engagement self-efficacy increased from 2.24 at the beginning of the course to 1.95 at the end of the course. On this survey, a lower score indicates a higher self-efficacy.

Qualitative analysis of written course reflections revealed that participants felt strongly that the course had positively impacted their understanding of engineering and how to teach it effectively. A common theme was that the course had given participants a better understanding of what different types of engineers do. According to one participant, *"Before this class, I couldn't give you an accurate answer as to what I thought engineering was or what engineers do."* Another participant added, "*I feel like I have a much stronger grasp on the definition of engineering and how to introduce it to students that are not in college yet and do not understand the complexity of engineering."*

An additional theme that emerged in the written reflections was that participants felt they had a better understanding of how to teach engineering as a result of participating in the course. For example, one participant wrote, "*I feel more confident now than I did at the beginning of the semester to teach engineering because I didn't know a lot about it before but now I know ways of incorporating it in other lessons."*

We also analyzed participant's written reflections to determine the impact of participating in the course on pre-service teachers' engineering teaching self-efficacy. Responses indicated that most participants felt much more confident in their ability to teach aspects of engineering in a K-12 classroom by the end of the semester. For example, one participant said, "*This class has given me a better understanding of how to approach engineering. Engineering is not as scary of a subject as I had expected it to be. Especially in the younger grades, I see that engineering can be advertised as a creative and inquiring subject, which I wish was advertised to me when I was younger."* Another participant simply said, *"I think it has boosted my confidence in teaching an engineering lesson a good bit."*

Conclusions

In this project, we developed a novel course model where pre-service STEM teachers and engineering undergraduate students collaborated to learn about STEM, create lesson plans, and engage in service learning in the community. Qualitative analysis of written reflections completed by students at the end of the course revealed that most participants felt that the course improved their understanding of engineering as a discipline, as well as their engineering teaching self-efficacy.

Acknowledgements

NSF-RIEF Grant 2106319

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