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Board 187: A Hybrid Community of Practice Model to Prepare Pre-Service STEM Teachers to Teach Engineering

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Abstract

In recent years, engineering has been increasingly incorporated into K-12 classrooms, even though K-12 teachers commonly have no prior experience with engineering or training in how to teach engineering. Therefore, schools cannot scale their programs to meet the criteria needed to teach engineering effectively. As a result, many teachers hold common misconceptions about what engineers do and have low self-efficacy with teaching engineering, leading to a lack of interest in engineering among K-12 students. Research indicates that students tend to hold stereotypical and narrow perceptions of engineering, which in turn limits their interest in engineering as a future career choice. Previous research indicates that to improve engineering literacy in the United States and support the professional formation of engineers, 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 where engineering practices can be most effectively integrated into the curriculum. However, there are currently very few colleges of education that provide any training to prepare pre-service teachers to teach engineering.

In this study, pre-service teachers and engineering undergraduate students worked together to learn about engineering education and develop engineering-focused activities for use in K-12 classrooms. A new course model was created that utilized a hybrid community of practice where students learned about engineering education and worked together to support local K-12 schools by engaging in service learning. This project explored the ways in which participation in this course impacted pre-service teachers' perceptions of engineering and engineering teaching self-efficacy. We first administered a survey designed to measure engineering teaching self-efficacy to 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 their confidence in their ability to teach engineering. They were also asked to reflect on their confidence in their ability to teach engineering in the future and on how their perceptions of engineering and self-efficacy had changed after participating in the course. All reflective journals were analyzed qualitatively using an open coding method to identify common themes in the responses.

The quantitative survey results demonstrated that the engineering teaching self-efficacy of pre-service teachers increased after participating in this course. Furthermore, in reflective journals, students indicated that they felt more confident in their ability to teach engineering by the end of the course, with many saying that they now had a better understanding of engineering as a field and how to teach it than they had before. Participants also stated that they felt like more exposure to engineering and training on how to teach engineering would further increase their self-efficacy and willingness to teach engineering in K-12.

Introduction

There is a recognized need to provide K-12 students with the opportunity to engage in authentic engineering practices, and this is emphasized in the standards of most states, as well as the *Next Generation Science Standards* [1,2]. Engineering provides a unique opportunity for students to hone their problem-solving skills and learn about potential career opportunities that they might not have otherwise considered. Previous studies have demonstrated that [*Understanding Science Teachers' Implementations of Integrated STEM Curricular Units Through a Phenomenological Multiple Case Study]* lessons or units that incorporate engineering can provide real-world context and support the development of students' problem-solving and communication skills [3]. Further, the incorporation of engineering into science content has been shown to have the potential to increase both student learning and interest [4].

To meet these demands, K-12 teachers are increasingly expected to incorporate engineering into existing math and science classes. Furthermore, in 2018, 46% of high schools offered dedicated engineering courses. However, most K-12 teachers, even those who are teaching standalone engineering courses, have little experience with engineering or training in how to teach engineering effectively. According to the 2018 Survey of Science and Mathematics Educators, less than half of the teachers who are currently teaching standalone engineering courses are certified to teach engineering and less than 20% have a major or minor in engineering or an engineering-related discipline. Furthermore, only 13% of high school science teachers have taken at least one course in engineering, and among elementary and middle school science teachers, only 3 and 10%, respectively, have taken at least one engineering course [5].

To communicate accurate information about engineering to K-12 students and design engaging 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, and this impacts their self-efficacy with teaching engineering. For example, teachers have been shown to often confuse the work of engineers with that of mechanics or construction workers or to assume that engineering is only attainable for students who are naturally gifted or come from higher socioeconomic backgrounds [6-8]. These inaccurate perceptions of engineering among K-12 teachers can impact the way that teachers introduce engineering practices and make connections between engineering and the other STEM disciplines [6].

Engineering teaching self-efficacy, which is defined as teachers' "personal belief in their ability to positively affect students' learning of engineering" [7,8], also affects the ability of teachers to engage students. Research indicates that high-efficacy teachers exert more effort and utilize more effective instructional strategies than low-efficacy teachers, which impacts the motivation of their students as well [11]. The Teaching Engineering Self-Efficacy Scale (TESS), a survey developed by Yoon and Strobel to measure the self-efficacy of K-12 teachers, has been used to demonstrate that the engineering teaching self-efficacy of current K-12 teachers is typically quite low [7,8,12].

One way to address this lack of engineering teaching self-efficacy among K-12 teachers is to provide pre-service teachers with more exposure to engineering and training in how to teach engineering. 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 Bachelor of Science in elementary education must complete a course in engineering design methods that is taught by faculty from the college of engineering [13]. 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 [14], while at Iowa State University, education and engineering faculty jointly teach a class for education majors called Toying with Technology [15], 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 [16]. Although all of these programs are promising, the effectiveness of this model of engineering teacher training has not yet been systematically investigated.

In this study, 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 by creating lesson plans and facilitating family STEM nights at local 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-Knoxville, the VolsTeach program was created to provide a pathway for undergraduate students pursuing a science, mathematics, or engineering degree to simultaneously obtain teacher licensure in Tennessee. All VolsTeach students are required to take an introductory course in STEM teaching (*TPTE 115: Intro to STEM Teaching*) during their first year in the program. This course includes content on STEM pedagogy and field experiences such as classroom observations and service-learning community outreach activities.

To provide the pre-service teachers enrolled in the VolsTeach program with more exposure to engineering, 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 this course, 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*) is 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. Examples course assignments are provided in Table 1.

Table 1: Example projects completed by students in EF327/TPTE115 [adapted from 17]

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 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.

Theoretical Framework

The theoretical framework for this research draws on social theories of learning occurring within communities 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 [18]." According to Wenger, communities of practice include three dimensions: mutual engagement, joint enterprise, and a shared repertoire. Mutual engagement occurs when people, who possess different contributions and competencies resulting from their individual experiences, learn and work together on a joint enterprise. As the community develops, the joint enterprise helps them make sense of what they are learning and facilitates the development of their identity as part of the community. As they work, they also develop a shared repertoire, which can include tools, discourse, artifacts, etc. [18]. Because the pre-service teachers and engineering students in the course have very different personal experiences and background knowledge, this course facilitates 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 [19,20]. Participation in such hybrid communities of practices has been demonstrated to facilitate identity development and self-efficacy growth in both teachers and students [20,21], and this project explores the ways in which participation in this hybrid community of practice with engineering students affects pre-service teachers' perceptions of engineering and self-efficacy with teaching engineering.

Methods

To examine the impact of participating in TPTE 115/EF 327, pre-service teachers enrolled in the class completed surveys and written reflections. 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. 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 3 semesters (Fall 2022, Spring 2023, and Fall 2023), and a total of 33 students completed both surveys.

Students also completed written reflections at the end of the course in which they answered questions about their perceptions of engineering, 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 written reflections. Each student was assigned a pseudonym, and then 2 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 and how those changed as a result of participating in the course.

Results and Discussion

The survey was administered at the beginning and end of the course for 3 semesters, and a total of 33 students completed it. After completing the course, participants experienced modest increases in both engineering content knowledge self-efficacy and engineering engagement self-efficacy. For the TESS survey, a lower score indicates a higher self-efficacy. 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.

However, even though the survey results revealed only a small change in self-efficacy, qualitative analysis of written course reflections revealed that the pre-service STEM teachers felt strongly that participating in the course had positively impacted their understanding of engineering and how to incorporate it into a K-12 classroom. A common theme present in written reflections was that the course had given them a better understanding of what different types of engineers do. According to one student:

> *"This class helped me gain a better understanding of what engineers do and all the different routes that engineers can take, like chemical engineering, civil engineering, computer engineering, etc. If I would have known more about engineering, I might have considered a career in engineering. This is why I think it is important to educate students on what engineering is and what engineers do."*

Another student commented that while they previously had a very limited understanding of engineering (i.e. building bridges and roads), participating in the class had opened their eyes to other aspects of engineering:

> *"I think this has opened my eyes to another aspect of engineering and to realize that it is not just building bridges and roads."*

An additional theme that emerged in the written reflections was that students felt they had a better understanding of how to teach engineering after participating in the course. For example, one student wrote:

> *"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."*

These results show that this collaborative course model can provide pre-service K-12 teachers with more accurate information about engineering as a field. In addition, many participants stressed that they felt more able to provide accurate information about engineering to K-12 students and that they felt that this was important.

We also analyzed written course reflections to determine the impact of participating in the course on pre-service teachers' engineering teaching self-efficacy. Most students who completed the course felt that their self-efficacy with teaching engineering had improved by the end of the course. Many indicated that they felt much more confident in their ability to teach aspects of engineering in a K-12 classroom:

> *"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."

"After taking this course I have a better understanding of how to teach engineering because during this semester we focused on new ways to teach a lesson and how to explain things and why it is important to teach engineering to students."

Some participants stressed the importance of explicitly explaining when engineering practices were being implemented to K-12 students. They felt that this would help K-12 students develop a better understanding of the types of work performed by engineers:

"I would consider implementing activities like this in my own classroom. I also think that it is important to be specific when explaining that those activities are engineering activities, so the students can identify situations that might involve engineers."

Although most students strongly indicated that they felt more confident in their ability to teach engineering, there were a few who felt that they had experienced more modest gains in self-efficacy. For example, one student wrote that even though he didn't feel completely comfortable with teaching engineering, he still felt that he would be able to use what he had learned in the course in some specific ways:

"This is something I will be able to accomplish.....at the very least, I feel like I could incorporate some kind of engineering concept into a math problem."

Out of the 33 students who participated in the research study, only one said that he didn't feel that the course had an impact on his self-efficacy with teaching engineering:

"To be completely honest, the class really hasn't changed my confidence in teaching engineering in the future. I just don't really know if it is for me, and if it is something that I will enjoy."

Overall, the results of this study indicate that almost all participants felt that the course had a positive impact on their self-efficacy, with only a few indicating that they felt like it had little or no impact.

Conclusions

In this project, we developed a novel hybrid community of practice course model where pre-service STEM teachers collaborate with engineering undergraduate students to learn about STEM pedagogy and work together to 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 had a positive impact on their understanding of engineering as a discipline and confidence in their ability to teach engineering. In future work, we plan to interview students who have completed the course to gain a better understanding of the long-term impacts of participation. We also plan to continue teaching the course and to create more opportunities for pre-service STEM teachers and engineering students to collaborate both in and outside of a classroom.

References

1. The National Academies of Sciences, Engineering, and Medicine Committee on Educator Capacity Building in K-12 Engineering Education. Building Capacity for Teaching Engineering in K-12 Education. Washington, DC: The National Academies Press, 2020.
2. NGSS Lead States. Next Generation Science Standards: For states, by states. Washington, DC: The National Academies Press, 2013.
3. E.A. Dare, J.A. Ellis, and G.H. Roehrig. "Understanding science teachers' implementations of integrated STEM curricular units through a phenomenological multiple case study." *International Journal of STEM Education* **5**(4), 2018.
4. S.S. Guzey, M. Harwell, M. Moreno, Y. Peralta, and T.J. Moore. "The impact of design-based STEM integration on student achievements in engineering, science, and mathematics." *Journal of Science Education and Technology* **26**, 2017.
5. E.R. Bannilower, P.S. Smith, K.A. Malzahn, C.L. Plumley, E.M. Gordon, and M.L. Hayes. Report of the 2018 NSSME+. Available online at http://horizon-reserach.com/NSSME/wp-content/uploads/2019/06/Report_of_the_2018_NSSME.pdf (accessed Nov. 1, 2020).
6. J Pleasants and J. K. Olson. "Refining an Instrument and Studying Elementary Teachers' Understanding of the Scope of Engineering." *Journal of Pre-College Engineering Education Research (J-PEER)* ***9***(2), 2019.
7. C. Cunningham, C. Lachapelle, A. Lindgren-Streicher. "Elementary teachers' understandings of engineering and technology." *ASEE Annual Conference and Exposition, Conference Proceedings*, 2006.
8. R. Hammack, J. Utley, T. Ivey, and K. High. "Elementary Teachers' Mental Images of Engineers at Work." *Journal of Pre-College Engineering Education Research (J-PEER)* ***10***(2), 2020.
9. S.Y. Yoon, M.G. Evans, J. Strobel. "Validation of the Teaching Engineering Self-Efficacy Scale for K-12 Teachers: A Structural Modeling Approach." Journal of Engineering Education **103**(3), 2014.
10. S.Y. Yoon, M.G. Evans, and J. Strobel, J. "Development of the Teaching Engineering Self-Efficacy Scale (TESS) for K-12 Teachers." *ASEE Annual Conference and Exposition, Conference Proceedings*, 2012.
11. M.H. Dembo and S. Gibson. "Teachers' Sense of Efficacy: An Important Factor in School Improvement." *The Elementary School Journal* **86**(2), 1985.
12. R. Hammack and T. Ivey. "Examining Elementary Teachers' Self-Efficacy and Engineering Teacher Efficacy." *School Science and Mathematics* **117**(1-2), 2017.

13. D. DiFrancesca, C. Lee, and E. McIntyre. “Where Is the "E" in STEM for Young Children? Engineering Design Education in an Elementary Teacher Preparation Program.” *Issues in Teacher Education* **23**(1), 2014.
14. S.W. Thomas, S.W. Campbell, M.D. Subramanyam, C.R. Ellerbrock. “Contemporary STEM issues: Engineering training of pre-service teachers for middle school STEM curriculum development.” *ASEE Annual Conference and Exposition, Conference Proceedings*, 2019.
15. L.J. Genalo, M. Gallagher, J. Golder. “An engineering linkage to K-12 teachers,” *ASEE Annual Conference and Exposition, Conference* F.C. Tseng and F.Y. Kuo. “A study of social participation and knowledge sharing in the teachers' online professional community of practice.” *Computers and Education* **72**, 2014.
16. S. O’Brien, J. Karsnitz, S. Van Der Sandt, L. Bottomley, E. Parry. “Engineering in pre-service teacher education.” In: *Engineering in Pre-College Settings: Synthesizing Research, Policy, and Practices*, eds. S. Purzer, J. Strobel, and M.E. Cardella. Purdue University Press, 2014.
17. B. Chesnutt, C. Faber, and D. Mountain. “Development of a hybrid community of practice course model to prepare pre-service teachers to teach engineering in K-12 (Work in Progress).” *ASEE Annual Conference and Exposition, Conference Proceedings*, 2022.
18. Wenger, E. *Communities of Practice: Learning, Meaning, and Identity*. Cambridge University Press, 1998.
19. K.D. Gutierrez, P Bacquedano-Lopez, and C Tejedo. “Rethinking diversity: hybridity and hybrid language practices in the third space.” *Mind, Culture, and Activity* **6**(4), pp 286-303, 1999.
20. Rahm, J. “Urban youths’ hybrid positioning in science practices at the margin: a look inside a school–museum–scientist partnership project and an after-school science program.” *Cult Stud of Sci Educ* **3,** 97, 2008.