# The impact of pre-service teachers' perceptions of engineering on their selfefficacy with teaching engineering


## Abstract

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. Studies have shown that K-12 teachers often confuse the work of engineers with that of automotive mechanics or construction workers or assume that engineering is only for "super smart" students who are naturally gifted or who come from higher socioeconomic backgrounds. This indicates that many teachers do not understand the nature of engineering work and have stereotypical attitudes about who is qualified to be an engineer. These inaccurate perceptions of engineering among K-12 teachers may influence the way that teachers introduce engineering practices to their students and make connections between engineering and the other STEM disciplines. In addition, 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. Research also indicates that high-efficacy teachers typically exert more effort and utilize more effective instructional strategies than low-efficacy teachers.

The goal of this study was to examine the perceptions that pre-service K-12 teachers hold about engineers and engineering, and to further explore how those perceptions influence their selfefficacy with teaching engineering and beliefs about what skills and resources are necessary to teach engineering in a K-12 classroom. We first developed a survey instrument that included questions taken from two previously published instruments: the Design, Engineering, and Technology survey and the Teaching Engineering Self-Efficacy Scale for K-12 Teachers. Fortytwo students enrolled in an undergraduate program at {Name Redacted} in which students simultaneously pursue a bachelor's degree in a STEM field and K-12 teacher licensure completed the survey. Based on survey responses, six participants, representing a range of selfefficacy scores and majors, were selected to participate in interviews. In these interviews, participants were asked questions about their perceptions of engineers and were also asked to sort a list of characteristics based on whether they applied to engineers or not. Finally, interview participants were asked questions about their confidence in their ability to teach engineering and about what skills and/or resources they would require to be able to teach engineering in their future classrooms.

The results of this study indicated that the participants' perceptions of engineering and engineers did impact their self-efficacy with teaching engineering and their beliefs about how well engineering could be incorporated into other STEM subjects. A recurring theme among participants with low self-efficacy was a lack of exposure to engineering and inaccurate perceptions of the nature of engineering work. These pre-service teachers felt that they would not be able to teach engineering to K-12 students because they did not personally have much

exposure to engineering or knowledge about engineering work. In future work, we will investigate how providing pre-service teachers with training in engineering education and exposure to engineers and engineering students impacts both their perceptions of engineering and self-efficacy with teaching engineering.

## Introduction

Even though K-12 teachers often have little experience with engineering, they are increasingly expected to provide K-12 students with opportunities to engage in authentic engineering practices. The Next Generation Science Standards, as well as the standards of many states, place a strong emphasis on integrating engineering practices into the science curriculum [1]. In addition, in 2018, 46% of high schools reported offering at least one stand-alone engineering course [2]. However, less than 20% of the teachers who are currently teaching these standalone engineering courses have a major or minor in engineering or an engineering-related discipline, and the majority are not certified to teach engineering [3]. In addition, it was reported in 2018 that only 3% of elementary teachers, 10% of middle school science teachers, and 13% of high school science teachers had completed even a single course in engineering [2].

Research has demonstrated that the perceptions that K-12 teachers hold about engineers and engineering are often inaccurate. When K-12 teachers were asked to draw an engineer, the images that predominated in these drawings included white males working alone and people wearing hardhats and working with tools, indicating that these teachers held stereotypical ideas about engineering work and who is qualified to be an engineer [4],[5],[6],[7],[8]. In addition to these inaccurate perceptions of engineering, the engineering teaching self-efficacy of K-12 teachers is also typically low [9],[10],[11]. Engineering teaching self-efficacy is defined as teachers' "personal belief in their ability to positively affect students' learning of engineering" [9],[10]. Previous research indicates that teachers with a low self-efficacy are less willing to engage with particular topics, put less effort into teaching, and utilize less effective instructional strategies [12],[13]. Although it has been demonstrated that K-12 teacher self-efficacy with teaching engineering is low, the influence of teachers' prior perceptions of engineering on their self-efficacy has not yet been examined. In this study, we will explore the following questions:

- What perceptions do pre-service STEM teachers hold about engineering and engineers?
- How do these prior perceptions impact the self-efficacy of pre-service STEM teachers with teaching engineering?
- What are the barriers that preservice STEM teachers believe are limiting their selfefficacy and what can be done to reduce these barriers?

## Methods A. Overview of Study Design

The participants in this study were undergraduate students enrolled in the VolsTeach program at the University of Tennessee Knoxville (UTK). The VolsTeach program allows students to complete a degree in a science, mathematics, or engineering field while obtaining teacher licensure. To explore the perceptions and self-efficacy of pre-service K-12 teachers enrolled in the VolsTeach program, a sequential explanatory mixed methods design was used [14].

### B. Survey Development and Participants

The survey that was completed by the pre-service teachers contained 4 sections, each of which was derived from a previously published survey. The first 2 sections included statements about engineering or engineers that participants were asked to place on a 6-point Likert scale, with 6 corresponding to strongly disagree and 1 corresponding to strongly agree. These statements were selected from a survey that was published in a National Academy of Engineering report [15]. Brief short answer questions were also added to this portion of the survey. For example, participants were asked to describe an engineer to an elementary, middle, or high school student and to list things that engineers might do in their careers. The third section of the survey was taken from the Design, Engineering, and Technology (DET) survey, which was designed to measure perceptions of engineering and motivation for teaching engineering [16]. Finally, the fourth section of the survey included questions from the Teaching Engineering Self-Efficacy Survey (TESS). This section included questions 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 selfefficacy with engaging students in engineering practices [9],[10].

A total of 41 students enrolled in 5 different VolsTeach courses completed the survey. The most common majors among the survey participants were mathematics (41%) and biology (20%), although many STEM fields, including engineering, were represented. 61% of the participants were either third or fourth year students, while 39% were first or second year students. Nineteen participants indicated that they would be willing to complete a follow-up interview, and interview participants were selected using their scores on the self-efficacy portion of the survey, with the goal of interviewing participants with varying self-efficacy scores.

### C. Interview Protocol Development and Participants

Six participants were selected to complete follow-up interviews. Each interview participant was assigned a pseudonym, as shown in the table below.

| *Participant* | *Major* | *Year* |
|---|---|---|
| *Megan* | Chemical Engineering | Fourth Year |
| *Sarah Claire* | Biochemistry and Cellular & Molecular Biology | Fourth Year |
| | Math Education | First Year |
| *Edward* | Chemistry | Third Year |
| | Mathematics | Fourth Year |

| | | |
|---|---|---|
| *Jacob John* | Biochemistry and Cellular & Molecular Biology | Fourth Year |

The interview consisted of 3 parts. In the first part, participants answered questions about their perceptions of engineering. Questions asked included:

- How would you define engineering?
- What skills or qualities are required to be an engineer?
- Is there anything that would prevent someone from being an engineer?

In the second part of the interview, participants were provided with a list of 33 words or phrases and asked to sort these based on how well they described engineers or engineering. Sort items included characteristics such as "prefer work as part of a team" and "great at math," and participants sorted the words or phrases on a scale from "no engineers do/are/have" to "all engineers do/are/have."

The sort procedure used in this study was a modified form of Q-sort methodology [Brown – Computer monitor]. As the participants sorted the items, the researchers asked questions to gather more information about their perceptions and any potentially unclear sort items. Participants were also given an opportunity to add any additional items to the sort that they felt were missing.

In the third part of the interview, participants discussed their self-efficacy with teaching engineering. They were asked questions about their construct scores from the survey and the factors they felt influenced these construct scores. They were also asked about how they could teach engineering in a future K-12 classroom, what resources they would need to be able to teach engineering, and what they considered to be the most important aspects of engineering to teach students. Finally, participants were asked what experiences or resources might improve their self-efficacy with teaching engineering.

**D. Analysis of Self Efficacy**

We characterized participants' self-efficacy with teaching engineering using data collected from both the survey and interview. By averaging each participant's scores for each question within each construct on the TESS part of the survey, we calculated an engineering content knowledge self-efficacy and engagement self-efficacy score for each participant. We also examined interview participants' responses to interview questions about their self-efficacy. Based on their responses, we created a codebook that included categories of responses such as things that were important to teach in an engineering class and what resources were necessary to successfully incorporate engineering into a STEM class, etc.

**E. Analysis of Perceptions of Engineering and Engineers**

We analyzed interview participants' perceptions of engineers by creating a codebook of their responses to questions in the first part of the interview, and by examining the data collected from the sort. This data included both the sort itself and participants' responses to follow-up questions.

**F. Analysis of Connection Between Perceptions and Self-Efficacy**

We examined the influence of participants' prior perceptions of engineering on their self-efficacy by holistically analyzing both survey and interview responses. Responses were recorded and compared to identify themes in each participant's responses. We looked at the themes identified within each participant's perceptions of engineering, and then looked for ways that these perceptions had influence their self-efficacy or the engineering content that participants felt they could teach in their future STEM classes. For example, if a participant felt that engineering requires good communication skills, we would look for evidence that they also felt it was important to teach communication skills as part of engineering in a K-12 classroom and if they felt like they were confident in their own ability to teach these skills.

**Results A. Self-Efficacy**

The average engineering content knowledge self-efficacy score was 2.81±2.94 for all participants, while the average engagement self-efficacy construct score was 1.91±0.90, indicating that most participants had a higher engagement self-efficacy than content knowledge self-efficacy. As shown in Figure 1, the content knowledge self-efficacy scores were much more variable than the engagement self-efficacy scores. Multiple participants had an average score above 4.0 for content knowledge self-efficacy, indicating that they had a very low self-efficacy in this area, while only one participant had a score above 4.0 for engagement self-efficacy. Taken together, these results indicate that participants' felt confident in their teaching ability regardless of the subject, but not as confident in their knowledge of engineering content.

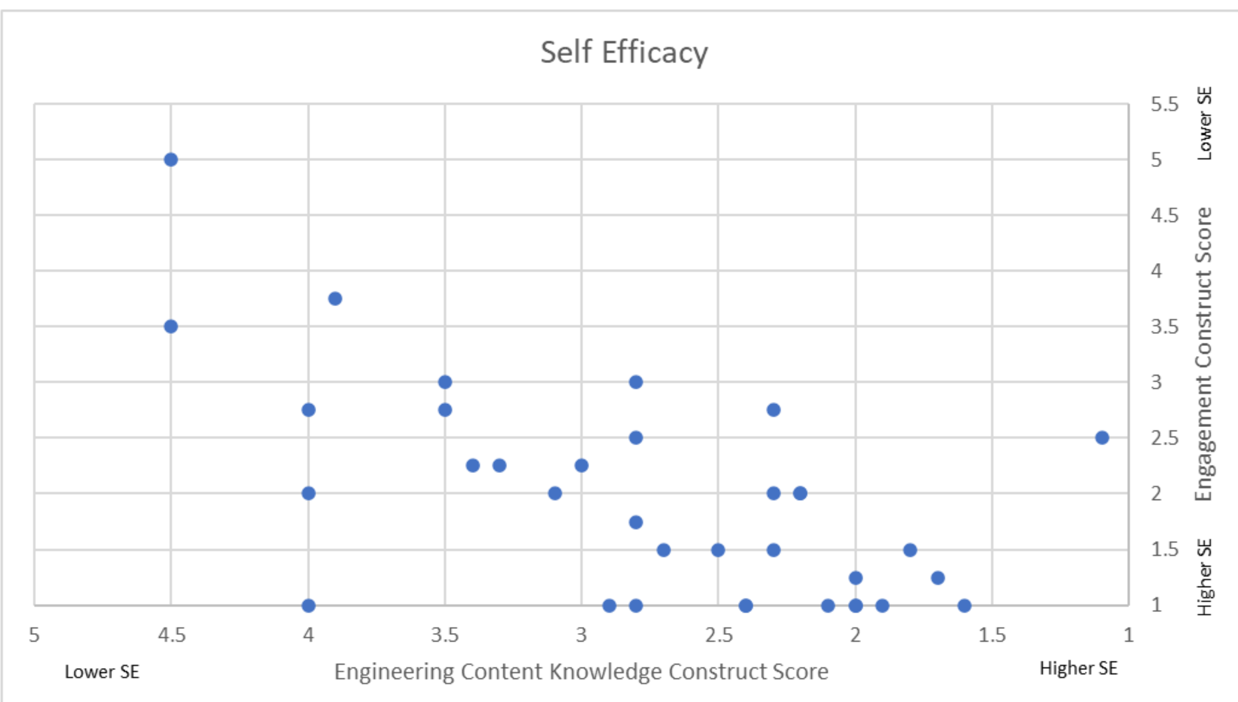


Figure 1: Plot comparing average construct scores from participants' survey data.

Interview participants were selected, in part, based on their content knowledge self-efficacy scores. As shown in Figure 2, the engineering content knowledge scores of interview participants varied from 1.25 to 4.80.

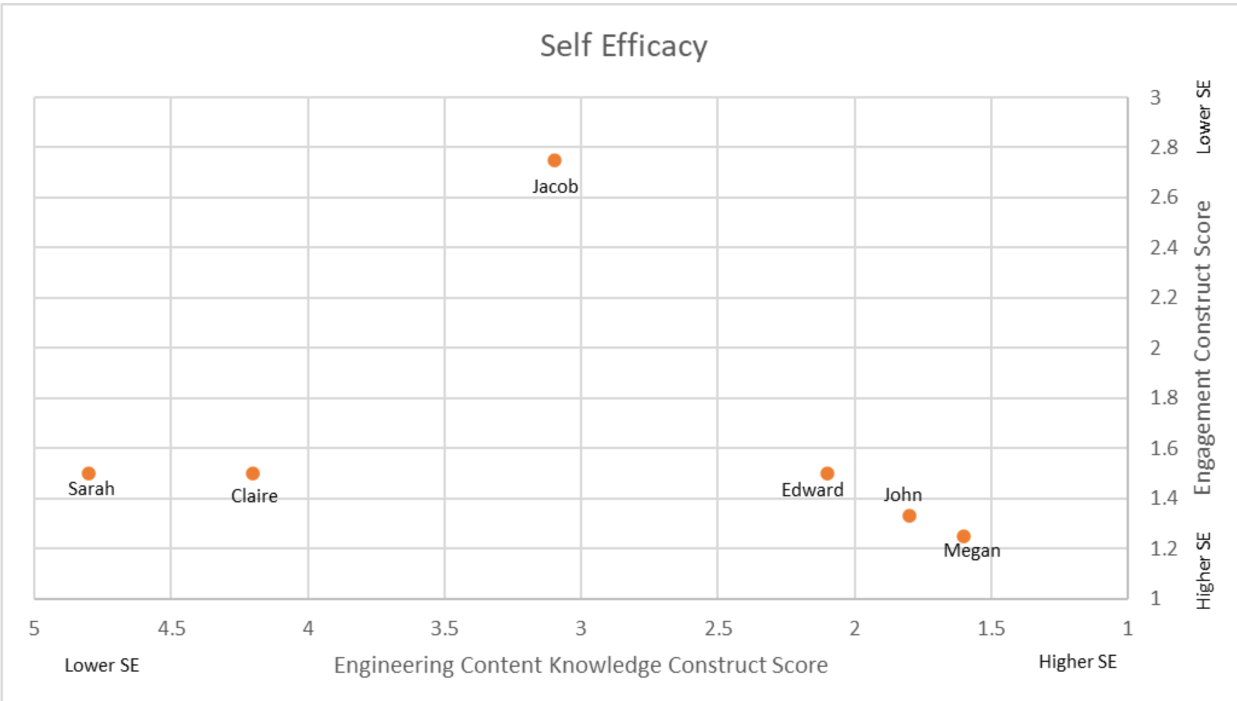


Figure 2: Plot comparing average construct scores from interview participants' survey data. Interviewed participants are labeled with pseudonyms

Two of the 6 interview participants, Claire and Sarah, had very low engineering content knowledge self-efficacies (construct score > 4.0). During the interview, they were asked what they felt contributed to this low self-efficacy. A common theme was that they had little experience with engineering. For example, Claire said "when I was in high school, there was no engineering classes or anything, like anything, like I didn't even know what that was until I got to college." This lack of experience with engineering was also mentioned by participants with higher content knowledge self-efficacies. Edward, who had a engineering content knowledge self-efficacy score that was relatively high, said "I know a lot of the engineering classes are more about..are knowledge based rather than like process based. But I, I still have not had that background...,like they have like their [first-year engineering] classes in the beginning where they're designing like the robots that like go on cars and stuff. Like I have, I've never done anything that, um, in depth with engineering."

Megan, who had the highest content knowledge and engagement self-efficacy out of all the participants, was also the only interview participant with engineering experience. When asked what she felt was responsible for her high self-efficacy with teaching engineering, she said, “I would say my experience in person as I’ve had 12 months of work experience as an engineer, and I’ve had dozens of classes at this point for engineering specifically.” She also had worked as a teaching assistant in a first year engineering class, and she also indicated that this experience with teaching engineering had also improved her confidence and self-efficacy, saying “my TA experience for teaching [first-year] engineering classes has made me a lot more confident in how I would be able to introduce engineering to students in the future.”

### B. Influence of Perceptions on Self-Efficacy

The participants’ perceptions of engineers and engineers impacted both their self-efficacy with teaching engineering and the specific skills they felt it was important to teach students. For example, most participants felt that engineers needed to be good at math and science, and they also felt that engineering content could be incorporated into a math or science classroom. However, even though he felt that engineering was important, Edward did not feel that he could easily incorporate any engineering into a chemistry class, which was the subject he planned to teach. He explained this by saying, “I feel like a lot of engineering would be hands-on work. Like if you had a specific engineering class, um, it would be very hands-on, um, in terms of designing and chemistry has a lot of hands-on stuff, but those are more scientific processes. Like, why does this happen rather than let’s design something to, um, that, that serves this cause.” He also described engineers as people who design and make things to solve specific problems and listed liking to build things and problem-solving as necessary traits of engineers during the sorting activity. According to him, engineers “make things or improve on things that are already made and then it serves some purpose,” and he felt like this would not be possible in a chemistry class where “a lot of the time you wanna spend doing these very hands-on and discussion-based activities, um, you want it to be about science and, and about discovering processes rather than, um, designing something.”

In contrast, Jacob, who intended to teach mathematics, said that he felt confident in his ability to incorporate engineering into a future class. He also indicated, in both the survey and interview, that he thought engineers needed to have good mathematics skills. According to him, engineers “need to have a pretty good understanding of, like, higher level mathematics,” and math teachers “need to have a good enough understanding that, like, when you’re trying to teach these mathematical relationships, you can get it down to a level that somebody learning can truly understand where it’s coming from rather than being just an equation.” Therefore, he felt that incorporating engineering into a math classroom would be beneficial for students. In particular, he felt that incorporating engineering practices would help students learn to revise and improve their work, and he felt that this was an important engineering skill to teach mathematics students.

Many participants felt that they needed to have specific traits or skills in order to teach engineering. For example, Sarah, who had a low self-efficacy, listed “creative” as a trait that strongly defined engineers during the sorting activity and also listed creative as one of the defining characteristics of engineers on the short-answer section of the survey. When asked what she would need to teach engineering in a K-12 classroom, Sarah said “creative supplies, like art supplies to see what they can come up with." However, she did feel confident in her ability to teach engineering because she did not consider herself to be a particularly creative person, saying, "I'm not the most creative person, like I am, but engineering wise, no, that's not for me." This indicates that her perception of engineers as very creative people had a negative impact on her self-efficacy with teaching engineering.

Megan had a high self-efficacy, and when asked what skills were important to teach engineering students, she said, "I would say that critical thinking, the deeper thinking, analyzing, um, understanding the cause and effect like where, how things relate to one another." Unlike Sarah, she did not feel like it was necessary to be a naturally creative person in order to teach engineering, and she felt that her previous experience in engineering had prepared her to teach critical thinking, saying, "I am comfortable, and I feel fairly confident. I think that following industry experience, I might be even more confident."

In summary, the perceptions that pre-service teachers already hold about engineers and engineering impact what skills they believe are necessary to teach engineering. This, in turn, impacts their self-efficacy with teaching engineering and their beliefs about whether it is even possible to incorporate engineering practices into other STEM courses.

### C. Barriers to Self-Efficacy

Many interview participants with low self-efficacies indicated that they had little exposure to engineering as a field, and they felt that more opportunities to learn about engineering would improve their confidence with teaching engineering, According to Edward, "I don't know if I have all of the skills that I would need to effectively teach that, I would probably need a little bit more engineering background or even just me designing more things would probably be good for a class like that." When asked what would raise his self-efficacy with teaching engineering, Jacob said, "I'd need to do it. Um, I would need to be an engineer. I would need to go and see it because I think that I don't do it justice." This indicates that providing opportunities for preservice and in-service K-12 teachers to engage in authentic engineering experiences is critical for providing them with more realistic perceptions of engineering and improving their self-efficacy with teaching engineering.

## Conclusions

The perceptions that pre-service K-12 STEM teachers hold about engineers and engineering impact both how they think engineering should be taught and their self-efficacy with teaching engineering. Many participants focused on a single skill that they thought was critical to teach in an engineering class, such as creativity, critical thinking, or the ability to design and build things. This, in turn, affected their self-efficacy in both positive and negative ways. For example, Megan believed that critical thinking was the most important skill to teach in an engineering class, and since she felt confident in her ability to teach critical thinking, she had a high self-efficacy. In contrast, Sarah, who did not consider herself to be creative, thought that creativity was the most important skill to teach, and consequently, had a low self-efficacy.

Almost all participants indicated that more exposure to engineering would help them become more confident with teaching engineering. In future work, we will investigate the impact of participating in a class designed to provide students with more exposure to engineering on the self-efficacy and perceptions of pre-service teachers.

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