2018 ASEE Annual Conference & Exposition
June 24–27, 2018
Salt Palace Convention Center
Salt Lake City, UT
Paper ID #24383

Investigation of Pre-Service Teacher Self-Efficacy for Teaching Engineering

Miss Jessica Lauren Sargent, Purdue University, West Lafayette

Jessica Sargent was born in Atlanta, Georgia. She received her B.S. in Polymer & Fiber Engineering from Auburn University and her M.S. in Chemical Engineering from Purdue University. Jessica is currently a graduate student at Purdue University working with the Women in Engineering Program and pursuing a Ph.D. in Materials Engineering.

Dr. Beth M. Holloway, Purdue University, West Lafayette

Beth Holloway is the Assistant Dean for Diversity and Engagement and the Leah H. Jamieson Director of the Women in Engineering Program (WIEP) in the College of Engineering at Purdue University. She is the current past chair of the Women in Engineering Division of ASEE. Holloway received B.S. and M.S. degrees in Mechanical Engineering and a Ph.D. in Engineering Education, all from Purdue University.

Mrs. Susan R. Bayley, Purdue University, West Lafayette
Anna Veronica Walter, Purdue University, West Lafayette

Investigation of Pre-Service Teacher Self-Efficacy for Teaching Engineering

Jessica L. Sargent,[1,2] Anna V. Walter,[1,2] Sue R. Bayley,[1] Beth M. Holloway[1]
[1]Women in Engineering Program, Purdue University, West Lafayette, IN 47907
[2]School of Materials Engineering, Purdue University, West Lafayette, IN 47907

Introduction

Historically, a significant portion of elementary and middle school educators' pre-service education has been dedicated to developing students' reading and writing skills, with some focus on mathematics and only basic coursework for teaching fundamental sciences. In recent years, many education programs have placed a heavier emphasis on math and science, and some now offer specializations within the bachelor's program for teaching these subjects. However, coursework related to engineering and technology remains limited.

With the introduction of the Next Generation Science Standards, science, technology, engineering, and mathematics (STEM) education has gained support, and a push has been initiated for elementary teachers to incorporate engineering design into their classrooms. Unfortunately, there are few, if any, opportunities for most pre-service and in-service teachers to learn and practice teaching engineering design. Initially inspired by the desire to improve the Access Engineering summer outreach program, the Purdue University Women in Engineering Program (WIEP) created such an opportunity for pre-service teachers. In order to evaluate the effectiveness of this opportunity, a study has been produced to assess and develop self-efficacy for teaching engineering in pre-service elementary educators.

Background and Motivation

University Outreach

Access Engineering

Accessing Engineering is an established engineering outreach program through WIEP that serves K-8th grade students at local summer camps. The program is under the direction of the Assistant Director of WIEP, who is a former elementary and middle school teacher, but all activities for this program historically have been led by Purdue University engineering students. While some engineering students have experience in the classroom, many do not. They are unfamiliar with common skills required of educators, such as how to maintain children's attention or resolve conflicts between students.

The goal of the Access Engineering program is to increase positive perceptions of engineering and engineers, raise interest in engineering in general, and provide information on how to pursue interests in engineering including eventual career paths. It is therefore crucial that engineering students remain involved in the program to serve as role models and team members who are comfortable with the content knowledge applied in the activities. However, it is believed that Access Engineering also could benefit greatly from leadership by those with experience in childcare and education. With these considerations in mind, pre-service teachers were employed as leadership team coordinators (*i.e.,* activity leaders), and engineering students were retained as leadership team (*i.e.,* activity assistants).

Novel Opportunities for Pre-Service Teachers

In addition to helping Access Engineering to better engage younger students in engineering activities, such an arrangement provides a unique experience for pre-service teachers through which they can learn about engineering design and how it can be incorporated into their future classrooms. Previous studies have been reported in which pre-service teachers are exposed to engineering through projects within a broader STEM-related course or through a dedicated methods course [1] – [8], but almost all engineering-related coursework is offered as electives. Even at Purdue University, engineering methods is not a required course in the elementary education curriculum. Interventions have also been designed for in-service teachers, often through workshops or other optional programs [8] – [10]. To the best of our knowledge, this work is the first to report the incorporation of pre-service teachers into engineering outreach instead of a formal classroom setting. This allows the pre-service teachers to gain experience without having to follow a pre-determined curriculum, design and grade student assessments, or be personally evaluated. These features of the informal setting of outreach provide a novel opportunity for pre-service teachers to gain experience in a low-stress environment.

Engineering Education

Engineering for K-12: The Next Generation Science Standards

The Next Generation Science Standards (NGSS) are a set of standards for K-12 education released in 2013 developed by the American Association for the Advancement of Science (AAAS) and the National Research Council (NRC). Many states have adopted the NGSS, and Indiana's science standards are based on the NGSS [11]. Despite the name, the NGSS also incorporates engineering and technology, encouraging teachers to weave engineering design into all aspects of the curriculum at all age levels [12]. Practically, the hope of incorporating engineering design into the classroom is to teach students to be better problem solvers. More broadly, it is hoped that using engineering design in science education will provide a way for under-represented groups (*e.g.*, females and minorities) to more easily engage with science [12]. Despite the adoption of NGSS by many states, adoption is voluntary and states do not receive any benefit from the federal government for doing so. Additionally, the NGSS are explicitly standards, not a curriculum, meaning a curriculum still needs to be developed and implemented.

Current State of Pre-Service Teacher Training for Engineering

In order to meet the NGSS, teachers will be required to develop individual curricula, and they also must be prepared to implement these curricula. Of special consideration are elementary (K-5) teachers, as they are trained as generalists; that is, they must teach all subjects. Much attention has been given to training teachers in literacy and mathematics, but little attention has been given to science and even less to engineering. At Purdue University, elementary education majors are required to take one math methods course and one science methods course, and these usually are not taken until late in the curriculum. There is one section of the science methods course available at Purdue University that focuses on engineering design. However, this section is not required and only impacts a limited number of students.

Impact of Teacher Beliefs: Self-efficacy

Self-efficacy, as defined by Bandura, is the belief in one's ability to succeed or achieve at something [13]. Self-efficacy is not confidence; one can be confident that one will fail. Self-efficacy is situation specific and task specific. For example, one may have high self-efficacy for doing well at reciting multiplication tables in front of a teacher but have low self-efficacy at doing well on an algebra test. Generally, having higher self-efficacy leads to having higher achievement, which in turn leads to higher self-efficacy [13].

For teachers, self-efficacy affects not only their own achievement, but also that of their students. In general, teachers with low self-efficacy set lower goals for their students, use inquiry projects less frequently, and see less success from their students [3]. Even more alarmingly, a study found that specifically for math, female elementary teachers can effectively "pass on" their math anxiety to their female students but not their male students [14]. In this study, the girls with higher math anxiety also had lower math achievement [14].

The clear majority of elementary teachers in the United States are female (>90%), so low self-efficacy in female teachers has the possibility of having a large negative impact at the elementary level. In general, pre-service and in-service elementary teachers have low self-efficacy for both teaching and learning science [15]. Note that this is not the same as their actual abilities in or knowledge of science, but the effect on students remains. Female teachers have lower self-efficacy in technical design [3], and elementary teachers in general have limited understanding of design, engineering, and technology [8]. However, it is possible to improve the self-efficacy of pre-service and in-service teachers in STEM subjects through various interventions [7], [16] – [18]. Therefore, despite the relatively low self-efficacy for female elementary teachers in STEM, there are methods of improving this self-efficacy, in turn promoting future success in their students.

Literature Review

Self-Efficacy and How it is Developed

Bandura identified four primary mechanisms through which self-efficacy is developed. These mechanisms do not work in isolation or in sequence but instead are known to increase self-efficacy in tandem. The four mechanisms are: mastery experience, vicarious experience, verbal persuasion, and physiological feedback [13].

Mastery experiences are experiences in which one personally succeeds at the task. Success is critical in building self-efficacy, and thus tasks are often purposefully increased in difficulty or intensity with time so that early success is possible [13]. Mastery experience may also include cognitive mastery, or an academic understanding of the subject at hand [17]. As there is little engineering in the formal elementary education curriculum, it is expected that cognitive mastery is very low in elementary educators. Additionally, pre-service teachers have few opportunities to teach alone until very late in the curriculum. When they do have the opportunity to teach, they are still supervised by an in-service teacher who most likely controls the content at some level, and engineering design is not commonly taught in elementary classrooms. With these two factors in mind, it is likely that elementary pre-service teachers have had little to no mastery experience with teaching engineering.

Vicarious experience is when one observes another succeeding at a task. As with mastery experience, success is necessary for the experience to contribute to self-efficacy [13]. In addition, this experience is most effective at increasing self-efficacy when the observer associates the one seen succeeding with themselves. That is, they must possess some similarities that allow the learner to identify with the one modelling. At Purdue University, elementary education students observe teachers throughout their curriculum, providing many opportunities for vicarious experience. However, again, it is likely that few practicing teachers use engineering design, therefore limiting the amount of vicarious experiences pre-service teachers have with teaching engineering.

Verbal persuasion includes encouragement from others as well as coaching. Verbal persuasion is most effective at increasing self-efficacy when the one doing the persuading is seen as an expert [13]. Exposure to verbal persuasion is also likely to be low for pre-service elementary teachers, as engineering design is not a focus of the pre-service curriculum. A major exception to this, as with mastery experience, would be those in the section of the science methods course at Purdue University that utilizes engineering design. These students actively design engineering concepts into science lesson plans with students. This provides mastery experience while the rest of the course ideally provides verbal persuasion.

Physiological feedback includes physical sensations from the body such as heartrate and changes in one’s mood [13]. A calm heartrate and pleasant mood improve self-efficacy while a racing heart and anxious mood lower self-efficacy. If one realizes that they are stressed by the situation, this can further lower self-efficacy. There are many methods suggested for reducing stress in participants, including repetition and creating a welcoming and cooperative environment.

Interventions for Teachers in STEM

Many interventions have been designed to influence the attitudes and behavior of pre-service and in-service teachers. Some have been designed specifically for science [1], [3], [17], technology [3], [5], or STEM in general [2], [4]. There are some related specifically to engineering [6], [7], and other interventions designed for in-service teachers to learn about engineering [9], [10]. Only one study was found that investigated the self-efficacy of pre-service teachers as it relates to teaching engineering [7].

Of those that studied the effect of the intervention on pre-service teachers’ attitudes about science, one used inquiry-based learning in a required science content course [1]. Participants in this course saw increased confidence and enjoyment as well as lower anxiety for teaching science. The pre-service teachers in a traditional lecture-based course saw a decrease in positive attitudes towards science [1]. While this result seems to favor inquiry-based learning for pre-service teachers, there was no direct measure of self-efficacy, although the investigators postulate that confidence is related to self-efficacy [1]. Another study found that there are many factors that may encourage or discourage pre-service teachers from implementing open-ended design activities during their teacher training [3]. Most commonly cited reasons for not incorporating such projects included lack of host teacher support [3]. It is suggested that using open-ended design projects to lead to more formal scientific inquiry may be beneficial for both elementary students and elementary teachers who lack content knowledge in science [3]. Neither of these studies directly evaluates the self-efficacy of pre-service teachers, although they offer valuable insight into potential best practices for teacher training programs.

Other studies focus specifically on technology, as technology integration courses in elementary education curricula are not uncommon. In one course, project-based learning (PBL) was used to teach pre-service teachers engineering design and fabrication. Such project-based approaches allow pre-service teachers to personally engage with project-based learning, a pre-requisite for its use in their future classrooms [5]. Furthermore, the use of hands-on activities can promote learning and a positive attitude toward the subject [5]. When using a closed-loop PBL model for an engineering design activity that also incorporated fabrication technology, it was found that elementary teacher candidates' self-efficacy as a technology-using teacher improved [2], [5]. Additionally, researchers found a stronger relationship between STEM careers and math and science after the intervention [5].

In addition to interventions designed to affect science and technology, others aim to influence STEM in general. In a course on using hands-on activities to integrate STEM for pre-service teachers, robotics were used as a tool to increase pre-service teacher engagement and interest in STEM [4]. Lesson plans developed by the pre-service teachers after this activity also show improved integration of STEM [4]. While this study perhaps sees the most positive effects after the intervention, self-efficacy is not specifically studied. Additionally, the use of robotics may be limited by a lack of experience of those designing teacher training.

There are some notable examples of engineering design being emphasized in elementary teacher preparation programs. In one such program, mathematics and science methods courses are emphasized, as well as a required extensive background in academic STEM subjects. Engineering design is utilized throughout the math and science methods courses, and there is also a required engineering methods course [6]. One project in this program aimed for pre-service teachers to create a lesson plan to integrate the STEM subjects using engineering design [6]. The pre-service teachers in this program had a positive attitude toward engineering and valued the engineering component of their education [6]. However, no quantitative data is reported on participants in this program and no self-efficacy indicators are reported.

Another program designed specifically for pre-service teachers to learn about engineering design was based on the "Engineering is Elementary" program out of the Museum of Science in Boston, MA and focused on female pre-service teachers [7]. In this program, female pre-service teachers observed a female non-engineer teach an engineering design activity, a type of vicarious experience. They then planned and implemented an engineering design project for elementary students, providing mastery experience [7]. Through interviews, it was found that both activities improved the female teacher candidates' self-efficacy for teaching engineering. Additionally, their understanding of engineering increased and they had a more positive view of engineering [7]. However, this study involved a very small sample size (five) and reported no quantitative data.

All of these examples offer lessons in designing teacher preparation programs that promote STEM. Together, they suggest that engaging pre-service teachers in hands-on, inquiry- or project-based activities can help improve their attitudes toward STEM. All studies suggest that by exposing them not only to STEM but also to these different teaching methods, pre-service teachers are more likely to incorporate these methods and STEM into their future classrooms. These studies all report positive effects on the pre-service teachers, including increased STEM engagement and enjoyment. These studies support the concept that pre-service teacher attitudes and self-efficacy can be influenced by vicarious and mastery experiences in teaching STEM.

Many interventions that focus specifically on engineering are designed for in-service teachers. In one such intervention, teachers were exposed to a week-long academy in which teachers were taught about engineering design and participated in engineering design activities in teams [10]. Analysis of teacher responses from before and after the academies showed an increased level of understanding of engineering at higher levels of Bloom's taxonomy [10]. This does not however indicate the teachers' abilities to teach engineering, only their personal understanding of what engineering is. In another study, teachers were taught about engineering, engineering design, and technology integration [9]. Data from these teachers and their students were collected; however, results are not publicly available for privacy reasons [9].

Of particular interest is a study on practicing teachers taking a graduate course on bridging engineering and education. The specific purpose of this course was to improve the self-efficacy of the teachers for teaching engineering through discussion of readings, working in small teams on engineering activities, and a final design capstone project [8]. For the women in the course, their self-efficacy in tinkering and technical design, two factors of self-efficacy for teaching engineering, improved throughout the course [8]. This increase was also present in a delayed post-test. It is proposed that such increase was not observed for the men in the course due to the high initial scores of the males on these factors [8]. This study supports the use of a cooperative and learner-focused environment for teaching STEM to improve self-efficacy [8].

Research Design

This study posed a unique opportunity to study pre-service teachers engaged in engineering outreach. As self-efficacy of teachers is known to have such a high impact on teacher behavior and student outcomes, it was chosen as the main area of investigation.
The main research questions in this study are:

- Do teachers who willingly participate in engineering outreach have higher self-efficacy for teaching engineering than other teachers?
- Does training pre-service teachers to lead engineering outreach activities increase their self-efficacy for teaching engineering?
- Does leading and assisting with engineering outreach increase the self-efficacy for teaching engineering in pre-service teachers?

The Study

About Access Engineering

Access Engineering is one of many outreach programs run by WIEP at Purdue University. Throughout the summer, Leadership Team members (LT) visit local summer camps, daycare centers, and other child care locations. One Leadership Team Coordinator (LTC) leads the activity and manages the other LT on site. Activities are designed by the Assistant Director of WIEP with a focus on engineering design. Activities consist of an introduction led by the LTC who introduces the LT, engineering, and the topic of the activity. The children then have one or more phases of a hands-on design activity which generally leads to some artifact or tangible product. The artifact that the children are asked to design and create always has at least one constraint and at least one criterion. Often children are given a mock budget in addition to other constraints and their artifacts are tested by the LT to determine if they meet the criteria. If time permits, they are allowed additional time or budget to redesign their artifacts. During the summer of 2017, there were over 60 Access Engineering visits, with an average of approximately 35 students at each visit and an LT to student ratio of 1:5. Participants range in age from kindergarten to 8th grade, although the majority are elementary age. In the past, all LT and LTC have been engineering students in all disciplines and stages of post-secondary education. In the summer of 2017, pre-service teachers were employed as LTC for the first time.

Methods

Developing Self-Efficacy

Pre-service teachers were recruited for Access Engineering from a variety of courses in the elementary education curriculum at Purdue University. Presentations by the authors were made in many different courses, including one section of a science methods course that focused specifically on using engineering design. Applicants were then interviewed and selected as either Leadership Team Coordinators (LTC) or Leadership Team members (LT).

There were 6 pre-service teachers that served as LTC; all were female elementary education majors at Purdue University. Although the study was proposed after their acceptance of employment, all 6 LTC agreed to participate in the study. All signed consent forms, and the study was approved as exempt by the Purdue University IRB. Those who served as LTC were exposed to a series of interventions designed to slowly increase their self-efficacy for teaching engineering. First, they were trained on engineering design and the logistics of the program. The sections on engineering design were led by the Assistant Director of WIEP, a former teacher, while the sections on logistics were led by an engineering graduate student. This was done to help build the pedagogical content knowledge and therefore the cognitive mastery of the pre-service teachers. It is assumed that the pre-service teachers would view the former teacher who now coordinates WIEP outreach as an “expert”, and so this training also contained aspects of verbal persuasion.

Later on the same day, the LTC assisted in the training of other LT, which included leading a practice activity. This was to help them build self-efficacy through a heavily guided mastery experience. The next phase of training was for the pre-service teachers to observe the experienced teacher leading actual outreach activities. The pre-service teachers acted as LT while the experienced teacher acted as the LTC. Each pre-service teacher observed one or two visits in this manner in order to build self-efficacy through vicarious experience. It was assumed that the pre-service teachers would more closely identify with the experienced teacher than with the engineering graduate student, regardless of the engineering-specific nature of the activities.

Throughout the summer, verbal persuasion continued through regular feedback from the engineering graduate student and experienced teacher. Additionally, pre-service teachers were provided regular mastery experience by leading outreach activities. The perception of mastery was further reinforced through the role of the LTC to oversee the visit and other LT on-site. In addition to serving as LTC, the pre-service teachers were offered the option of serving as LT on more visits. Out of 66 total visits, each pre-service teacher attended in some capacity (LT or LTC) 18 – 38 visits. Pre-service teachers made up approximately 50% of all LT on visits. By allowing the pre-service teachers to regularly work together, a welcoming and cooperative environment was encouraged. The pre-service teachers informally met before and after visits to collaborate on methods and share advice on the visits, which ideally also improved their physiological state. In addition, the lack of formal evaluations of the pre-service teachers fostered a relaxed environment. There were six pre-service teachers as LTC and two who served only as LT. Those who only served as LT were not included in this study as they were not present in person at training and therefore were unable to give consent.

Another group of pre-service teachers was recruited from a summer course on literacy. These pre-service teachers worked in teams to design activities and implement them at one of the visits. These teachers received training similar to that given to the other pre-service teachers. Less information on the logistics of visits was given. Again, this was designed to build cognitive mastery and use verbal persuasion to build self-efficacy. Both the experienced teacher and the engineering graduate student worked with these teachers to design their activities and provide regular feedback, offering further verbal persuasion. The entire group observed one activity led by the experienced teacher and then each team designed and led an activity.

Measuring Self-Efficacy for Teaching Engineering

Self-efficacy was measured at multiple points throughout the training and summer program (Figure 1) in an attempt to determine the effect of individual self-efficacy building activities. Self-efficacy was measured immediately prior to LTC training as a baseline or starting point. It was then measured again after LTC training and before LT training. This allowed us to isolate the effect of training on self-efficacy. Self-efficacy was measured again after approximately half of all visits were completed. Unfortunately not all pre-service teachers went on visits that were evenly distributed throughout the summer, and therefore this measurement was not necessarily at the halfway point of mastery experiences for all pre-service teachers. Additionally, the number of visits in which each pre-service teacher served as LT or LTC were not evenly distributed; some pre-service teachers had the majority of their experience leading the activities in the latter half of the summer. A final measurement of self-efficacy was acquired from 5 of the 6 participating LTC within 2 weeks of the last visit. For the pre-service teachers that did not serve as LTC (*i.e.,* those recruited from the literacy class), an initial measurement of self-efficacy was administered prior to training, but subsequent requests for measurement yielded few to no respondents.

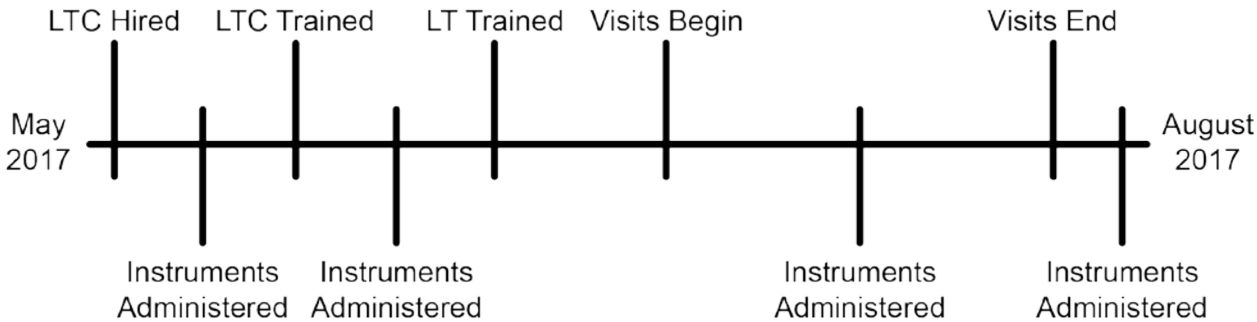

Figure 1. Intervention Timeline. Survey instruments were administered at the indicated points relative to self-efficacy building activities.

Three instruments were used to measure self-efficacy; each instrument was used at every administration of the survey. Instruments were administered using the online Qualtrics platform. These three instruments were used because no one individual instrument met the goals of the study and had been validated for pre-service teachers. There were instruments validated for pre-service teachers' self-efficacy in teaching science [19] and math, but none were found that were specific to both engineering and pre-service teachers. The instruments chosen all had validity evidence with relatively high coefficient alphas, although not all had confirmatory factor analyses.

The first instrument is the Design, Engineering, and Technology (DET) survey. The DET survey is a 40-item instrument that uses a 4 point Likert scale. There are 4 factors in the DET survey: Importance of DET, Familiarity with DET, Stereotypical Characteristics of Engineers, and Barriers to Integrating DET [20]. For DET, the individual factors and overall instrument have high reliability, ranging from 0.77-0.91 and the factors have been confirmed with an exploratory and confirmatory factor analysis [20]. The DET survey has been independently validated twice on in-service elementary teachers [21], [22]. During development of the instrument, responses indicated that teachers thought DET was important and should be taught. However, they had low confidence in integrating DET into their classroom, low familiarity with DET, and held many common stereotypes about engineers [21]. These findings were all on in-service teachers, and some items in the survey may not be applicable to pre-service teachers. For example, the question "Did your pre-service curriculum include any aspects of DET?" Students who are earlier in the education curriculum may not yet have encountered science or math methods courses which is where one would typically encounter DET in an elementary education curriculum.

The next instrument was the STEM Semantics survey. This consists of five scales, each of which has 5 adjective pairs [23]. The five scales are science, technology, engineering, mathematics, and STEM careers. Each scale shows good reliability, with an exploratory factor analysis that confirmed the five factors [23]. In the administration of the instruments for this study, there was an error in one of the items in the engineering scale; an adjective pair was repeated and another omitted. This instrument broadly measures interest in STEM and STEM careers, not specifically engineering nor the teaching of engineering. However, it has been utilized with pre-service teachers [23]. Among middle school students, in-service teachers, and pre-service teachers surveyed, pre-service teachers had the lowest results on the math and engineering subscales [23].

The third instrument was the Teaching Engineering Self-efficacy Scale (TESS). The TESS is a six-point Likert scale with five subscales: engineering pedagogical content knowledge self-efficacy, engineering engagement self-efficacy, engineering disciplinary self-efficacy, engineering outcome expectancy, and teaching engineering self-efficacy [24]. The TESS also has good validity evidence as well as confirmatory factor analyses. However, the TESS also assumes a unified definition of engineering used by all respondents. Additionally, many items, especially those in the engineering engagement and disciplinary self-efficacy subscales, refer to "my students". Those pre-service teachers that are early in their educations may not identify as having students that are "theirs" yet due to their limited teaching experience.

Analysis and Results

Survey instruments were administered at the four stages described above: 1) before any training, 2) after LTC classroom training but prior to training other LT, 3) approximately halfway through Access Engineering visits, and 4) after the conclusion of all Access Engineering visits. Instrument results are presented by survey administration, followed by interpretation of results with respect to each portion of self-efficacy building activities or the intervention as a whole.

As suggested by its name, the TESS survey instrument provided the clearest measure of the pre-service teachers' self-efficacy for teaching engineering. The twenty-three survey items were grouped according to six overarching teaching abilities for analysis: (1) the ability to recognize and discuss engineering concepts with students, (2) the ability to plan and employ engineering activities in the classroom, (3) the ability to guide students in engineering activities, (4) the ability to assess students' work on engineering activities, (5) the ability to encourage students in engineering activities, and (6) the ability to manage a classroom during engineering activities. A continuous increase in self-efficacy with respect to each of these abilities was quantifiably determined from multiple administrations of this survey throughout the summer program (Figure 2).

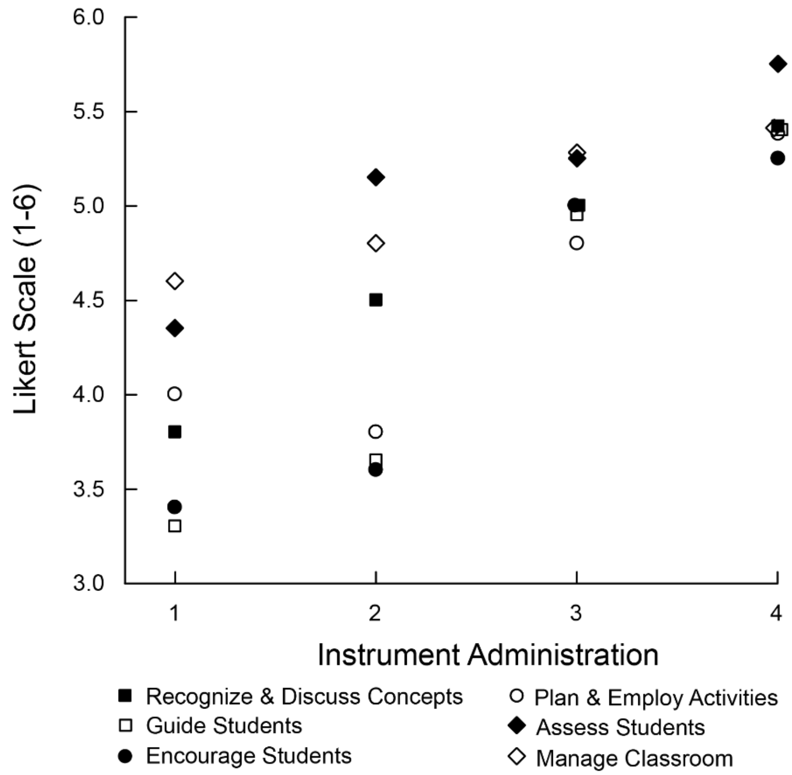

Figure 2. Self-Efficacy in Teaching Engineering. The TESS survey instrument asks teachers to assess their perceived ability (*i.e.*, self-efficacy) to perform certain roles or actions related to teaching engineering.

It may be observed that some abilities increased far more drastically than others. However, it also should be noted that the abilities for which less change was observed are those abilities most closely related to universal traits for teachers (*e.g.*, classroom management and encouraging students). The initial, relatively high ratings of these abilities indicate that the pre-service teachers were more comfortable with their ability to perform these roles, at least in a general sense, upon entering the study. Thus it is logical that they would not need as much assistance in improving self-efficacy in these areas as they related to engineering.

Results from the DET survey provide further supporting evidence for the success of this intervention. The DET survey focuses primarily on the participant's beliefs about DET methodology (Figure 3) and perceptions of engineers (Figure 4) and is less-directed at specific teaching roles than the TESS survey. The beliefs about DET illustrated in Figure 3 have been divided into interest in applying DET (3a) and current confidence regarding the methodology (3b). Figures 3a and 3b indicate that the pre-service teachers entered the summer program with only moderate interest in learning and applying DET methodology in the classroom and relatively low confidence in their knowledge and use of DET. For the majority of these metrics, we see the desired increase in scores over the course of the intervention. However, Figure 3b also presents an unexpected progression of scores for two of these metrics: education on DET and use of DET in the classroom.

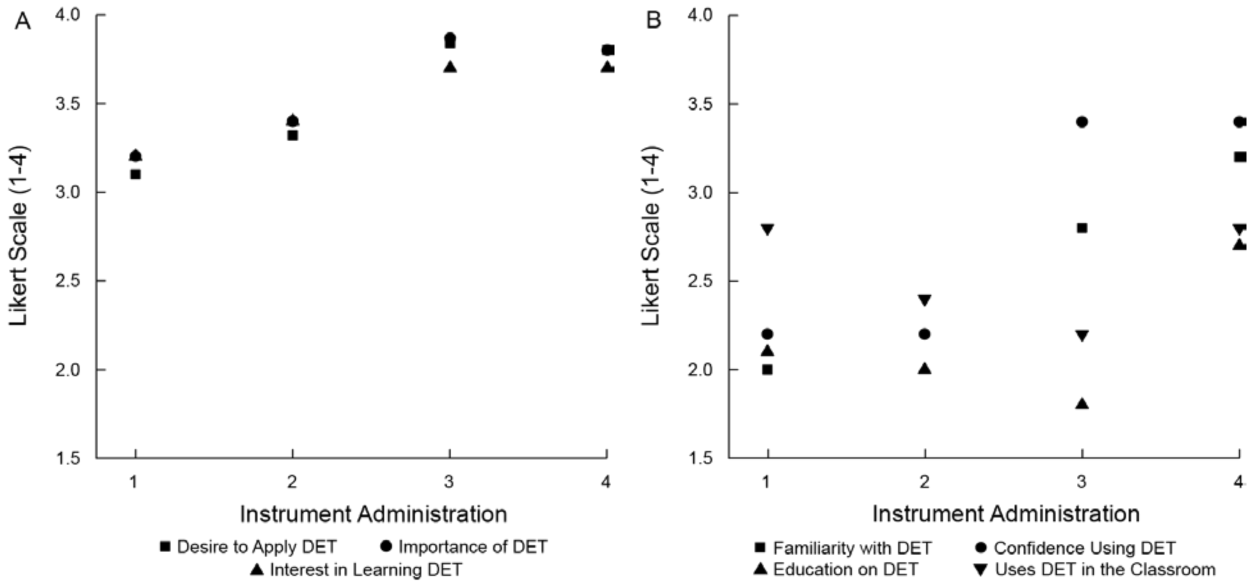

Figure 3. Beliefs About DET. (A) Pre-service teachers' interest in learning and applying DET methodology. (B) Pre-service teachers' confidence in their knowledge and use of DET.

It appears from these results that pre-service teachers entered with the beliefs that they were fairly well educated in DET and capable of applying it in the classroom. At some point during the program, the scores dropped below their initial values before returning to a final value higher than the starting value. This progression was initially surprising, but there is a theory that we believe could explain the unusual data referred to as the Dunning-Kruger Effect [25]. In 1999, Kruger and Dunning proposed that incompetence is a double-edged sword. The incompetent lack the metacognitive ability to recognize relative competence in themselves and others and therefore rate themselves as more competent than they truly are [25]. Kruger and Dunning also posited that, through interventions, this metacognitive ability would improve alongside an individual's realistic competence. Therefore the individual would at some point develop the metacognitive skill to recognize that they are not highly competent, lowering their self-evaluation [25]. However, once the individual reaches a high level of competence, he or she is likely to assume that others are equally as competent [25]. The other "edge" is then manifested in a rating of the individual's competence as lower than reality due to the assumption that they are no more competent, relatively, than others. This theory has been supported by subsequent studies by other investigators [26] – [28] and could explain the drop in scores observed midway through our program and the relatively low scores reached at the conclusion of the intervention.

Figure 4 illustrates a shift in pre-service teachers' perceptions of engineers that is in line with the goals of the Access Engineering program. Perceptions of engineers' communication and "people" skills improved markedly, as did the view that engineers are "fixers" and problem solvers. Scores decreased for believing engineers are good at math and science, which could be interpreted as the pre-service teachers realizing that one does not have to "love" math and science to be an engineer. Math and science are simply tools that engineers must be able to apply to solve problems. This sentiment in particular is a guiding principle within the WIEP outreach programs, as we hope to dispel the myths that either one has to "love" math and science in order to be an engineer (*i.e.*, cannot be an engineer otherwise) or that one ought to be pushed into a career in engineering because they are very adept at math and science. Finally, a notable decrease was seen in the perception that engineers earn good money. We believe this could be a product of improved understanding that many people work as engineers because they want to solve problems and have an impact on the world around them, not just because it "pays well."

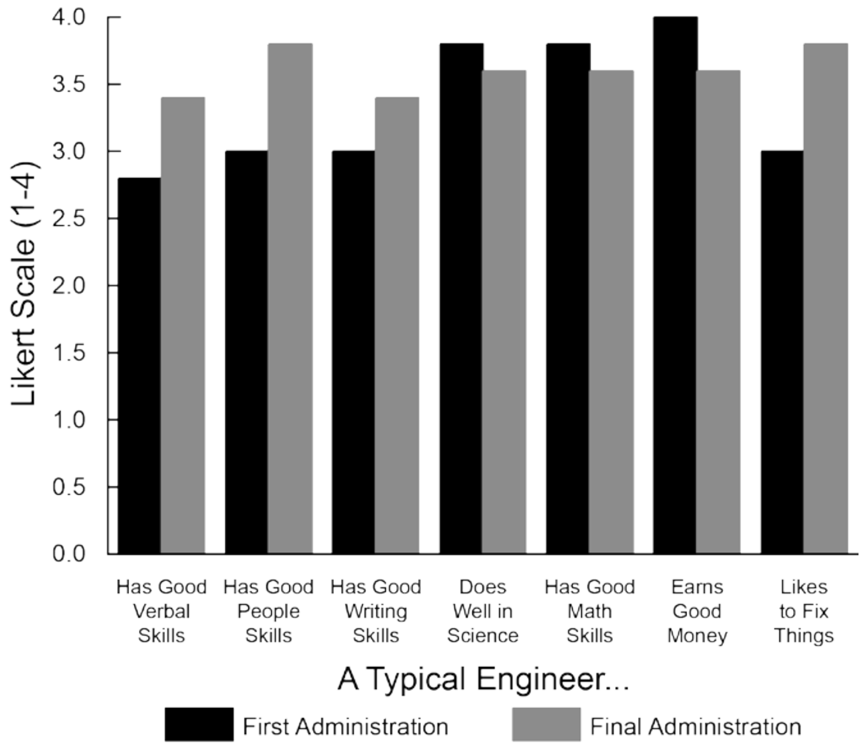

Figure 4. Perceptions of Engineers. Scores from the first and fourth survey administration are compared to illustrate changes in pre-service teachers' perceptions of engineers over the course of the program.

The final survey instrument administered, the STEM Semantics survey, produced no substantial trend. This is not unexpected, as this survey inquires as to the level of appeal each aspect of STEM (*i.e.*, science, technology, engineering, math, and STEM careers) holds for the participant. Pre-service teachers rated each field relatively evenly throughout the summer, whether they entered the study with an attraction to, dislike for, or apathy toward STEM fields. This intervention was not an attempt to make engineering every teacher's favorite subject or to convince anyone to pursue further interest in a specific topic. The purpose of this intervention was to improve self-efficacy for teaching engineering, the success of which is well supported by other survey results.

Conclusions and Plans for Study Continuation

In this study we have discussed a novel program which integrates pre-service teachers into engineering outreach. The self-efficacy of the pre-service teachers for teaching engineering was evaluated throughout the program and results of the pilot study were reported. The relatively steady increase in evaluation scores at each administration of the survey instruments suggests that each step of the intervention was successful in further building self-efficacy. This gradual change also supports the idea that no one step or mechanism was responsible for the results of the intervention but rather that the mechanisms work cohesively.

This pilot study was composed of a small sample size, which limits the statistical significance of results at this time. Statistical analysis is anticipated upon increasing the study's sample size in the coming year. Additionally, we recognize that some items in the survey instruments utilized may not be applicable to pre-service teachers. However, we believe initial results indicate that this intervention provides an effective method for building self-efficacy in pre-service teachers for teaching engineering. We thus present here an overview of future plans for the continuation of this study.

In order to increase statistical significance, we seek to hire new pre-service teachers for Access Engineering 2018. We will conduct the program in a similar fashion and administer the same survey instruments. However, we would also like to invite participants in Access Engineering 2017 to return for 2018. By combining new and returning pre-service and in-service teachers, we will be able to investigate several additional factors as they relate to self-efficacy in teaching engineering.

By having previous participants return and participate in a similar program a second time, we can evaluate the impact of intermission of practice on self-efficacy. One of the previous participants is now an in-service teacher and may have had opportunity to employ what she learned in the 2017 program, but the other four participants will have spent the 2017-2018 school year in traditional coursework with little to no opportunity to practice utilizing engineering design or teaching engineering.

By bringing veterans alongside new participants, we will be able to study the effects of their interaction on one another. Does having returning LTC teach new LTC increase the self-efficacy of the new LTC over what was achieved by the study designers in 2017? Does teaching new LTC further increase the self-efficacy of the returning LTC? These questions and more could be answered by comparing survey results from the pilot study with those of the 2018 expansion of the study.

Finally, it is hypothesized that incorporating additional pre-service teachers as both LTC and LT could produce a more cohesive leadership team. In 2017, engineering students still filled a large portion of leadership, and many of these students were enrolled in summer courses or committed to other priorities. A number of engineering students in leadership is still desirable for providing role models and content masters, but by having more teachers in these positions, the goals and expectations of the leadership team could be better aligned, resulting in a greater positive impact on both the pre-service teachers and the children reached by this program.

Through this study, we aim to impact multiple groups and generations. Foremost, we endeavor to better prepare the pre-service teachers who participate in this program for a career in an evolving education community as it seeks to incorporate engineering design into all levels of education. We also strive to improve the impact of the Access Engineering outreach program, encouraging more children to pursue interests in engineering. However, measurement of such impact is beyond the scope of this study, which is focused on teacher self-efficacy. Finally, through the formal investigation of this program, we aim to ultimately design a new intervention that can be employed broadly to improve the self-efficacy of both pre-service and in-service teachers for teaching engineering, thus preparing future generations to make a global impact.

References

[1] C. Riegle-Crumb, K. Morton, C. Moore, A. Chimonidou, C. LaBrake, S. Kopp, "Do Inquiring Minds Have Positive Attitudes? The Science Education of Preservice Elementary Teachers," *Sci. Educ.* vol. 99, pp. 819-836, 2015.

[2] C. Alexander, G. Mayes, S. Hopper, S. Thiruvadi, and G. Knezek, "An Investigation of the Impact of Digital Fabrication Projects on Pre-Service Teachers' Attitudes and Skills" in *Proceedings of th Society for Information Technology and Teacher Education International Conference, SITE 2012 Austin, TX, USA, March 5-9, 2011,* P. Resta, Ed. Chesapeak, VA: Advancement of Computing in Education, 2012. pp. 1025-1032.

[3] J. L. Bencze, "Promoting student-led science and technology projects in elementary teacher education: Entry into core pedagogical practices through technological design," *Int. J. Technol. Des. Educ.* vol. 20, pp. 43-62, 2010.

[4] C. Kim, D. Kim, J. Yuan, R. B. Hill, P. Doshi, C. N. Thai, "Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching," *Comput. Educ.* Vol 91, pp. 14-31, 2015.

[5] C. Alexander, G. Knezek, R. Christensen, T. Tyler-Wood, and G. Bull, "The Impact of Project-Based Learning on Pre-Service Teachers' Technology Attitudes and Skills," *Jl. Comput. Math. Sci. Teach.* vol. 33, pp. 257–282, 2014.

[6] 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 Teach. Educ.* vol. 23, pp. 49–64, 2014.

[7] S. Wendt, J. K. Isbel, P. Fidan, and C. Pittman, "Female Teacher Candidates' Attitudes and Self- Efficacy for Teaching Engineering Concepts," *Int. J. Sci. Soc.* vol. 7, pp. 1836–6236, 2015.

[8] D. Baker, S. Krause, S. Yasar, C. Roberts, and S. Robinson-Kurpius, "An Intervention to Address Gender Issues in a Course on Design, Engineering, and Technology for Science Educators," *J. Eng. Educ.* vol. 96, pp. 213–226, 2007.

[9] H. A. Diefes-Dux, "Introducing engineering in elementary education: A 5-year study of teachers and students," *Br. J. Educ. Technol.* vol. 46, pp. 1015–1019, 2015.

[10] D. Duncan, H. Diefes-Dux, and M Gentry, "Professional Development Through Engineering Academies: An Examination of Elementary Teachers' Recognition and Understanding of Engineering," *J. Eng. Educ.* vol. 100, pp. 520–539, 2011.

[11] S. Cavazos, "New Indiana science standards would stress skills over memorizing facts," *Learning Science*, April 14, 2016. [Online]. Available: http://in.chalkbeat.org.

[12] Next Generation Science Standards, "APPENDIX I - Engineering Design in NGSS," pp. 1–7, April 2013.

[13] A. Bandura, "Self-efficacy mechanism in human agency," *Am. Psychol.* vol. 37, pp. 122–147, 1982.

[14] S. L.Beilock, E. A. Gunderson, G. Ramirez, and S. C. Levine, "Female teachers' math anxiety affects girls' math achievement," *Proc. Natl. Acad. Sci. U. S. A.* vol. 107, pp. 1860–1863, 2010.
[15] W. Harlen, "Primary Teachers Understanding in science and its impact in the classroom," *Res. Sci. Educ.* vol. 27, pp. 323–337, 1997.
[16] R. E. Bleicher and J. Lindgren, "Success in science learning and preservice science teaching self-efficacy," *J. Sci. Teach. Educ.* vol. 16, pp. 205–225, 2005.
[17] D. Palmer, "Sources of efficacy information in an inservice program for elementary teachers," *Sci. Educ.* pp. 577-600, 2011.
[18] Y. Lee and J. Lee, "Enhancing pre service teachers self efficacy beliefs for technology integration through lesson planning practice," *Comput. Educ.* vol. 73, pp. 121–128, 2014.
[19] L. D. Smolleck, C. Zembal-Saul, and E. P. Yoder, "The development and validation of an instrument to measure preservice teachers' self-efficacy in regard to the teaching of science as inquiry," *J. Sci. Teach. Educ.* vol. 17, pp. 137-163, 2006.
[20] T. Hong, S. Purzer, and M. Cardella, "A Psychometric Re-Evaluation of the Design, Engineering and Technology (DET) Survey," *J. Eng. Educ.* vol. 100, pp. 800–818, 2011.
[21] S. Yasar, D. Baker, S. Robinson-Kurpius, S. Krause, and C. Roberts, "Development of a Survey to Assess K-12 Teachers' Perceptions of Engineers and Familiarity with Teaching Design, Engineering, and Technology," *J. Eng. Educ.* vol. 95, pp. 205-216, 2006.
[22] M.-C. Hsu, S. Purzer, and M. E. Cardella, "Elementary teachers' views about teaching design, engineering, and technology," *J. Pre-College Eng. Educ.* vol. 1, pp. 31–39, 2011.
[23] T. Tyler-Wood, G. Knezek, and R. Christensen, "Instruments for Assessing Interest in STEM Content and Careers," *J. Technol. Teach. Educ.* vol. 18, pp. 341–363, 2010.
[24] S. Yoon Yoon, M. G. Evans, and J. Strobel, "Validation of the teaching engineering self-efficacy scale for K-12 teachers: A structural equation modeling approach," *J. Eng. Educ.* vol. 103, pp. 463-485, 2014.
[25] J. Kruger and D. Dunning, "Unskilled and Unaware of It: How Difficulties in Recognizing One's Own Incompetence Lead to Inflated Self-Assessments," *J. Pers. Soc. Psychol.* vol. **77**, pp. 1121-1134, 1999.
[26] L. T. Tan, "Innovations in Continuing Professional Development – Countering the Dunning-Kruger Effect," *Clin. Oncol.* vol. 23, pp. 659-661, 2011.
[27] P. Bell and D. Volckmann, "Knowledge Surveys in General Chemistry: Confidence, Overconfidence, and Performance," *J. Chem. Educ.* vol. 88, pp. 1469-1476, 2011.
[28] A. B. H. de Bruin, E. M. Kok, J. Lobbestael, A. de Grip, "The impact of an online tool for monitoring and regulating learning at university: overconfidence, learning strategy, and personality," *Metacognition and Learning*, vol. 12, pp. 21-43, 2017.