Professional Development for K-12 Math Teachers and Its Immediate Effect on Engineering Self-Efficacy

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Introduction

As the need for Science, Technology, Engineering, and Mathematics (STEM) focused careers increases, there is a large movement to embed engineering in K-12 classrooms, hoping to increase student interest in engineering early and as a result launch them into STEM careers for the future. While the Next Generation Science Standards (NGSS)[1] emphasize engineering in K-12 science classes, teaching engineering content is relatively new and different for most K-12 math teachers. That lack of familiarity creates a disconnect between societal need and successful incorporation of engineering in K-12 classrooms. As a result, professional development for math teachers that introduces engineering and helps them better understand how they can best incorporate engineering into their curricula is becoming more fundamental. This paper describes the development of experiential learning modules for middle and high school math classes and their use for effective professional development opportunities for K-12 math teachers. The professional development opportunity included an introduction to engineering, the presentation of 14 experiential learning modules, and a create-your-own module session for 22 middle and high school math teachers over the course of three days. The participating teachers were asked to complete the Teaching Engineering Self-Efficacy Scale (TESS) survey [2] before and after the professional development opportunity along with a follow-up satisfaction survey. The paper also discusses the immediate effect of professional development on teachers' engineering self-efficacy along with their overall impression of the professional development opportunity.

Background and Supporting Literature

Attrition rates in engineering and other STEM disciplines as a whole hover around 50% nationally. Data from the Science and Engineering Indicators 2016 report [3] shows that the percentage of students who pursue a STEM degree is directly proportional to the highest math course taken in high school, specifically courses beyond Algebra II. However, many students are still not "math ready" upon entering college. A study by Gleason et al. [4] found that math placement has a strong correlation to retention rates in engineering. They found that students who placed in College Algebra or below accounted for only 10% of engineering graduates and those who placed in Pre-calculus accounted for nearly 40% of dropouts. Likewise, Santiago and Hensel [5] found that 34% of students who left engineering due to academic difficulties noted specific difficulty with Calculus I.

Engineering outreach programs geared at increasing awareness of and interest in engineering among secondary education students have been proposed as one solution to the problem of attrition [6-19]. These programs may focus on students, teachers, and/or the curriculum [20]. Student-focused programs typically introduce students to the field of engineering using hands-on activities [9, 21, 22], but many of the activities (e.g. balsa wood bridge competitions, prepackaged building kits, etc.) lack an analytical component, which may give students a false representation of engineering programs [13]. Teacher-focused programs usually consist of professional development opportunities to improve teachers' engineering awareness and ability to teach engineering related content [11, 21]. The goal of such programs is to integrate engineering content in math and science classes to improve student performance, while simultaneously increasing student interest and engineering awareness [9, 21, 22]. However, most approaches focus on teaching the engineering design process in math and science classes (mostly science) [11, 12, 18, 23, 24], rather than teaching math and science in the context of engineering. Large-scale curriculum programs, such as *Project Lead the Way* and *The Infinity Project,* mainly include stand-alone pre-engineering courses. While such programs complement existing math and science courses, they require students to be enrolled in a college prep math sequence or complete certain math courses (e.g. Algebra II) prior to enrollment [11]. There are very few programs in the United States that introduce engineering in the context of existing math and science curricula.

While the primary goal of engineering outreach programs is to increase awareness and interest, most programs do not consider preparation and retention, and university remedial programs are often too late to fix the problem. The benefit to students, faculty, colleges, universities, and society is minimal when students pursue a major they may not wholly understand, or may not adequately be prepared to pursue. Engineering outreach programs need to not only focus on introducing students to the field, but also help affirm students' interest and understanding, and aid in their preparation to more efficiently impact the number of engineering graduates. The issue is not the ability to generate interest in engineering, but rather preparing students to succeed and affirming their understanding of engineering.

Gaining Early Awareness and Readiness for Undergraduate Programs

The Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP) is a "discretionary grant program designed to increase the number of low-income students who are prepared to enter and succeed in postsecondary education. GEAR UP provides six-years or seven-years grants to states and partnerships to provide services at high-poverty middle and high schools. GEAR UP grantees serve an entire cohort of students beginning no later than the seventh grade and follow the cohort through high school. GEAR UP funds are also used to provide college scholarships to low-income students [25]." Similarly, the mission of the National Council for Community and Education Partnerships (NCCEP) is to "build the capacity of communities to ensure that underserved students have the opportunity, skills, and knowledge to successfully pursue the education and training that will enable them to achieve their career and life goals. We work towards a future where all students are empowered and equipped with the education and training needed to succeed in a diverse and global society [26]." GEAR UP and NCCEP have worked together since their concurrent beginnings resulting in great success.

The strategy of NCCEP [26] focuses on three points, Excel, Prove, and Mobilize, descriptions of which are listed below:

> "Excel—Developing a mindset of continual improvement and equipping GEAR UP professionals and youth with the skills necessary to maximize their programmatic impact."

"Prove—Ensuring that GEAR UP programs and professionals have the necessary skills, capabilities, and infrastructure to make informed decisions based on sound data, research, and evaluations."

"Mobilize—Strengthening our collective voice to secure the long-term sustainability and growth of GEAR UP locally and nationally."

As a result of that strategy, GEAR UP programs across the country look for partnerships that align with those three points. In recent years many of those programs have focused significant resources on STEM initiatives. The Lafayette Parish School System's GEAR UP (Lafayette GEAR UP) program has partnered with several entities over the years to potentially inspire and/or increase student interest in STEM-related subjects. Those partnerships have resulted in after-school coding clubs, engineering experiences for students, professional development for teachers, and STEM summer camps. One particular initiative focused on professional development for teachers included the development of experiential learning modules for math classes that align with current curricula and state standards. Carroll et. al [19] highlighted the best practices and lessons learned for planning new programs and discussed how one such STEM initiative evolved over time to focus on the teachers. A partnership with Saint Louis University (SLU) led to the creation of several experiential learning modules, which has since spread to other GEAR UP programs (e.g. Oregon GEAR UP).

The Oregon GEAR UP Program's primary goal is to increase the number of low-income students who are prepared to enter and succeed in postsecondary programs. The program supports rural Oregon middle and high schools in their efforts to set high academic expectations, promote early awareness of college opportunities, and engage students in college and career planning. Program staff make data-driven decisions to assist schools in meeting the needs of their communities. Through this approach, Oregon GEAR UP staff identified a need for improvement in mathematics and science outcomes for students across all participating schools. Schools have implemented initiatives to increase rigor and success in math and science by building new tutoring programs, increasing class time for math and science instruction, and offering dual credit courses. That same need led to Oregon GEAR UP offering professional development opportunities for math and science teachers similar to that created through the Lafayette GEAR UP Program and SLU; Oregon GEAR UP ultimately partnered with SLU to offer a professional development opportunity for their middle and high school math teachers.

Module Development

The experiential learning modules were developed over the course of four years as part of the Lafayette GEAR UP Program which involved assessing the need in the curriculum and what concepts students struggled with most in previous years. Analyzing test scores and student records showed that many students struggled to understand various concepts in math, such as geometry, algebra, probability, etc. Analyzing data further revealed more specific topics such as fractions, slopes, and Pythagorean theorem that students had difficulty with year after year. These topics were brainstormed into connecting them with engineering in everyday life and "real-world" problems. The general format of every module consists of teacher resources and the student module. The teacher resources are one page summaries describing what STEM topic and profession is used in this module, a summary of math concepts that the module covers, an interactive example that the teachers use to guide students, and the required and optional resources needed for the module [20]. The student module is the engineering-based math challenge to work through, that covers a specific topic from their math curriculum, and a free-response reflection for students to express what they learned about engineering and about STEM through the module [20]. Modules highlight different areas of engineering, including but not limited to civil, aerospace, and biomedical engineering. Table 1 shows the different modules and their corresponding objectives along with associated level/course. The modules align with existing state and national standards and illustrate various mathematical concepts in the context of real-world applications related to various STEM careers. Nearly 25 modules were developed during that time, 14 of which are described hereafter that were used for the professional development opportunity in cooperation with Oregon GEAR UP.

Professional Development Workshop

The professional development workshop included a three-day seminar for 22 Oregon K-12 math teachers in conjunction with the Oregon GEAR UP program. The professional development opportunity included an introduction to engineering, the presentation of 14 experiential learning modules, and a create-your-own module session. The primary goal of the project was to increase the self-efficacy of teachers by providing training on the use of math-based experiential learning modules for their classrooms and to develop their own content. The agenda is shown below, and Fig. 1 shows several photos from the workshop.

Table 1—Descriptions of experiential learning modules used for the professional development seminar.

Course	**Module**	**Objective**
Grade 7	Fractions in Football	Illustrate the relationship between fractions, decimals, and percentages in the context of sports. Students will calculate fractions and convert those fractions to decimals and percentages to compare those quantities.
	Unit Rates in Civil Engineering	Apply unit rates to a real-world problem and estimate costs. Students will use given dimensions, unit rates, and labor rates to estimate the final project costs, while simultaneously learning about civil engineering.
	Estimating Probabilities	Estimate the probability of different outcomes based on a given sample. Students will take a sample of data and simultaneously learn about eight different engineering disciplines: Aerospace, Biomedical, Chemical, Civil, Electrical, Mechanical, Nuclear, and Petroleum.
Grade 8	Slopes of Non-vertical Lines	Calculate the slopes of various lines and compare their values. Students will use the provided baseball field templates to visualize the relationships.
	Pythagorean Theorem	Visualize the Pythagorean Theorem and then apply it to a real-world problem. Students will use the provided baseball field templates to visualize the relationships.
	Linear Equations in Baseball	Determine the equations of three lines that represent the path of a batted ball and the paths of two outfielders trying to catch the ball before it hits the ground. Students will use the provided baseball field templates to visualize the equations and make a real-world connection.
Algebra I	Optimization in Production I	Introduce students to the concept of optimization of areas. Students will create various sizes of rectangles to determine which combination of length and width will produce the largest areas.
	Optimization in Production II	Expand upon students' understanding of optimization. Students will construct various sizes of boxes to determine the maximum possible volume created from a single piece of cardstock.
Geometry	Optics and Geometry	Visualize the differences and similarities among geometric volumes. Students will calculate the volumes of various shapes, compare the values, and estimate weights given a density.
	Geometric Shapes and da Vinci	Determine several geometric properties associated with the *Vitruvian Man*. Students will create their own *Vitruvian Man* (or Woman) and make several calculations based on their drawing.
	Geometric Tower Design	Design and construct a model overlook/lookout tower capable of supporting the design load and evaluate the geometric properties of the structure. Students will construct their own structure and use that structure to complete various tasks.
Algebra II	Gravitational Acceleration	Determine the acceleration due to gravity. Students will conduct an experiment, plot various relationships, and make several calculations.
	Cubic Functions and Volumes	Expand upon students' understanding of cubic functions. Students will write cubic functions to represent volumes of boxes, graph the functions, and explain what happens at the point where the two curves intersect.
	Probability with Dice	Describe how sample data relates to theoretical probabilities. Students will use dice to generate their own sets of sample data and then evaluate that data.

Day 1—Tuesday, July 30th

9:00 am	Welcome and Introductions
9:10 am	TESS Survey (via laptop/phone)
9:30 am	Visual Learning Activity (understanding your students)
10:00 am	Introduction to Engineering
10:15 am	*Grade 7 – Estimating Probabilities*
10:45 am	Break
11:00 am	*Grade 7 – Fractions in Football*
11:15 am	*Grade 8 – Slopes of Non-vertical Lines*
12:00 pm	Lunch
12:45 pm	ASCE Dream BIG Film
1:30 pm	*Grade 7 – Unit Rates in Civil Engineering*
2:30 pm	Break
2:45 pm	*Algebra I – Optimization in Production I*
3:15 pm	*Algebra I – Optimization in Production II*
4:00 pm	Design-your-own Module Brainstorming Session
4:30 pm	Wrap-up

Day 2—Wednesday, July 31st

9:00 am	*Geometry – Geometric Tower Design*
10:15 am	Break
10:30 am	*Algebra II – Probability with Dice*
11:00 am	*Geometry – Geometric Shapes and da Vinci*
12:00 pm	Lunch
12:45 pm	*Grade 8 – Pythagorean Theorem*
1:30 pm	*Grade 8 – Linear Equations in Baseball*
2:15 pm	*Break*
2:30 pm	*Algebra II – Cubic Functions and Volumes*
3:15 pm	*Algebra II – Gravitational Acceleration*
4:00 pm	Design-your-own Module Brainstorming Session
4:30 pm	Wrap-up

Day 3—Thursday, August 1st

9:00 am	*Geometry – Optics and Geometry*
10:00 am	Jig-saw Activity
11:00 am	Guided module development
12:00 pm	Lunch
12:45 pm	Continued module development
2:00 pm	Break
2:15 pm	Finalize modules
3:00 pm	Module presentations by participants
4:00 pm	TESS Survey
4:30 pm	Wrap-up

(a) (b)

(c) (d)

(e) (f)

Figure 1—Teacher work through the (a) Unit Rates in Civil Engineering Module; (b) Linear Equations in Baseball Module; (c) Optimization in Production I Module; (d) Geometric Shapes and da Vinci Module; and (e) Geometric Tower Design Module, and (f) present their own module.

Assessment Methodology

The authors assessed the short-term impact of the professional development seminar on teacher self-efficacy. The Teaching Engineering Self-efficacy Survey (TESS), a tool developed to measure teacher preparedness with regard to engineering related content, was given to the participants prior to the PD seminar and then again after [2]. Questions from the survey can be found in Table 2 and were taken from the TESS Survey created by Yoon et. al [2]. Questions were divided into categories based on the TESS survey guidelines, which can also be seen in Table 2.

Participating teachers were asked to complete the TESS survey at the beginning of Day 1, prior to any professional development (pre-test) and then again at the end of Day 3, following the professional development (post-test). Responses were provided on a 6-point Likert-type scale ranging from 1=Strongly disagree to 6=Strongly agree. Additionally, the participating teachers were asked to take a follow-up survey focused on their overall satisfaction with the professional development seminar. The following questions were asked regarding the seminar (institute): what did you learn during the Summer Institute that you will apply in your work/school; what motivated you to attend this year's Summer Institute; what could have made the Summer Institute a better or more applicable learning experience for you? Results were summarized and have been interpreted below.

Table 2—Teaching Engineering Self-Efficacy Survey Items

Engineering Content Knowledge Self-Efficacy	
1	I can discuss how engineering is connected to my daily life.
2	I can recognize and appreciate the engineering concepts in all subject areas.
3	I can spend the time necessary to plan engineering lessons for my class.
4	I can employ engineering activities in my classroom effectively.
5	I can craft good questions about engineering for my students.
6	I can discuss how given criteria affect the outcome of an engineering project.
7	I can guide my students' solution development with the engineering design process.
9	I can assess my students' engineering products.
Instructional Self-Efficacy	
8	I can gauge student comprehension of the engineering materials that I have taught.
Engagement Self-Efficacy	
10	I can promote a positive attitude toward engineering learning in my students.
11	I can encourage my students to think critically when practicing engineering.
12	I can encourage my students to interact with each other when participating in engineering activities.
13	I can encourage my students to think creatively during engineering activities and lessons.
Disciplinary Self-Efficacy	
14	I can calm a student who is disruptive or noisy during engineering activities.
15	I can get through to students with behavior problems while teaching engineering.
16	I can keep a few problem students from ruining an entire engineering lesson.
17	I can control disruptive behavior in my classroom during engineering activities.
18	I can establish a classroom management system for engineering activities.
Outcome Expectancy	
19	When students get a better grade in engineering than he/she usually gets, it is often because I found better ways of teaching that student.
20	When my students do better than usual in engineering, it is often because I exerted a little extra effort.
21	If I increase my effort in engineering teaching, I see significant change in students' engineering achievement.
22	I am generally responsible for my students' achievements in engineering.
23	My effectiveness in engineering teaching can influence the achievement of students with low motivation.

Assessment Results

The surveys had a range from 1-6 on the Likert scale, as previously described in the methodology. To code the data, responses were given points from 1-6 with respect to the Likert scale, i.e. if teacher responded Strongly Agree, a 6 was coded. The coded data was used as quantitative numbers to calculate descriptive statistics for the study. Individuals received 23 coded results for their pre-test, and 23 coded results for their post-test.

The professional development training was successfully conducted, resulting in 22 completed pre and post surveys, with a 100% response rate. Data was interpreted by classifying survey questions into 5 categories, which were adapted from TESS Survey guidelines provided by Yoon et. al [2]. Categories included Engineering content knowledge self-efficacy, Instructional self-efficacy, Engagement self-efficacy, Disciplinary self-efficacy, and Outcome expectancy. These had 8, 1, 4, 5, and 5 questions respectively. The individual coded self-efficacy scores were taken, and sums were found for each category. Within the sums that individuals received for each category, a minimum, median, maximum, mean, and standard deviation was calculated. This was done for both pre and post surveys. A t-test was conducted to evaluate the significance between the two tests. Table 3 lists the descriptive statistics for the data. Self-efficacy scores given to each participant per category can also be seen as box-and-whisker plots in Figure 2. Finally, a total self-efficacy score was also given for each participant in which the sum of all questions was taken, and a t-test was done between pre and post-tests for significance.

Table 3—Descriptive Statistics of Pre- and Post-test TESS Survey

Table 3 Descriptive Statistics of TESS Survey from PD

N = 22		Min	Median	Max	Mean	Std. Dev.
Engineering content knowledge self-efficacy	Pre	13	29	46	27.96	8.25
	Post	29	37.5	46	37.23	4.43
Instructional self-efficacy	Pre	1	4	6	3.36	1.47
	Post	3	5	6	4.77	0.69
Engagement self- efficacy	Pre	7	17	24	17.32	4.99
	Post	16	21.5	24	21.32	2.42
Disciplinary self- efficacy	Pre	13	22.5	30	22.09	4.79
	Post	16	25	30	24.54	3.73
˙Outcome expectancy	Pre	15	21.5	30	22.23	4.13
	Post	19	25	30	24.27	3.35
Self-efficacy individual totals	Pre	59	94.5	120	92.95	18.09
	Post	90	114	131	112.14	11.77

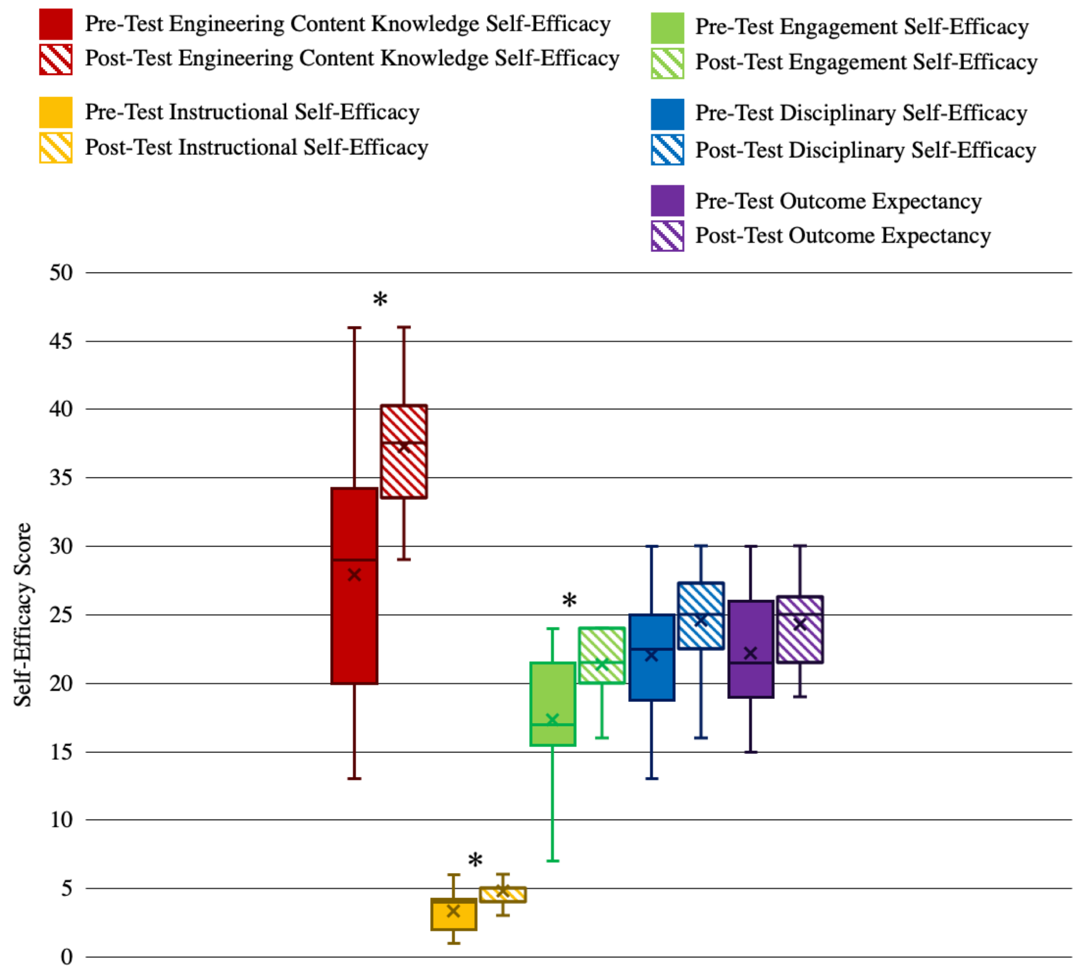

Figure 2—Self-efficacy score of participants pre-test and post-test. Scores of all questions from self-efficacy pre-test and post-test categorized into 5 topics are represented as box-and-whiskers plots. The lower (Q1) and upper (Q3) quartiles represent observations outside the 9-91 percentile range, the median is represented by the central darker line in the boxes, and x indicates the mean self-efficacy scores for participants. Data falling outside of the Q1-Q3 quartile are plotted as outliers of the data. * indicates statistical significance where $p<0.001$.

Engineering content knowledge self-efficacy refers to the teachers' personal beliefs on their own knowledge of engineering and how to incorporate that knowledge within their teaching curricula [2]. A total of 8 questions were used for this category, which ranged from comfort in discussing engineering in daily life to how well they can teach it, with a total maximum score possible of 48. Results from the pre-tests in this category displayed participants had a maximum score of 46, minimum score of 13, and average of 27.89 with a standard deviation of 8.25, showing a range of 33 between individuals for their baseline knowledge. The minimum post-test self-efficacy score for *Engineering content knowledge self-efficacy* increased by 16 points, with a 9.27 rise in average score and a 1.86-fold decrease in standard deviation. A paired t-test between the pre-test and post-test of the 22 participants showed a statistically significant mean difference between the two, with a $p = 0.000034$ ($p<0.05$). The statistical difference and increased median between pre- and post-test shifted the histogram for *engineering content knowledge* to the left.

These results are indicative that after participating in the professional development training, teachers demonstrated more confidence in their engineering background and their ability to relay that information to students, which can be seen in Figure 2.

Instruction self-efficacy is the instructors' personal confidence in their ability to teach engineering in order to facilitate learning [2]. Only one question fell under this umbrella; therefore, results are solely based on the responses to this question, with a max total score possible for this category of 6. Participants scored a maximum pre-test value of 6 and minimum pretest value of 1, and average score of 3.36, with a standard deviation of 1.47; this is reflective of the variation between participants, however overall, the sample scores averaged in the middle. In comparison to post-tests, there was a 2-point increase in minimum, raising the minimum score from 1 to 3, showing that many more participants felt confident about this question after the professional development. Although the average only went up by 1.41 points, the data was statistically significant, and the standard deviation had a 2.13-fold drop in variation between individuals, indicating a lot less variation between individuals after the professional development, and more overall confidence in teachers' ability to teach engineering to facilitate learning. A paired t-test between the pre-test and post-test of the 22 participants showed a statistically significant mean difference between the two, with a $p = 0.00019$ ($p<0.05$). It is important to note that this analysis is only based on one question and if more questions in this category had been asked, a more accurate and reliable overview of instructional self-efficacy would be observed. Significance can be seen in Figure 2.

Engagement self-efficacy is the teachers' personal confidence in their ability to engage their students while teaching engineering [2]. This section consisted of 4 questions, ranging from promoting positive attitudes and critical thinking towards engineering, to encouraging students to interact and engage with each other. The maximum possible self-efficacy score for this category is 24, where participants had a minimum of 7 and maximum of 24 for the pre-test, and minimum of 16 and maximum of 24 for post-test. A 9-point difference between minimum self-efficacy scores for pre- and post- professional development, and 4-point increase in average self-efficacy score was observed. There was also statistical significance between pre-test scores and post-test scores, and a 2.06-fold decrease in standard deviation, indicative that participants showed less variation in their self-efficacy scores after the professional development was administered. A paired t-test between the pre-test and post-test of the 22 participants showed statistical significant mean difference between the two, with $p = 0.0016$ ($p<0.05$). These results conclude that teachers displayed more self-confidence in their ability to engage students while teaching engineering after the professional development workshops than before, which is also represented through the box and whisker plots in Figure 2.

The next category, *disciplinary self-efficacy*, refers to the instructors' personal belief in their confidence to cope with a wide range of student behaviors during engineering activities [2]. This category contained 5 questions, regarding disruptive and problematic students and teachers' ability to cope with and manage them. With a total maximum possible score of 30, only a 3-point difference between the minimum for pre- vs post- test was observed, and when comparing, there was no significant difference seen between the pre- and post- tests. A paired t-test between the pre-test and post-test of the 22 participants resulted in no statistically significant mean difference between the two, with a $p = 0.065$. This most likely indicates that teachers have a defined way of discipline that they implement regardless of which subject they are teaching. Although they may handle engineering instruction slightly different, according to the survey, their overall management styles have not changed after the professional development. Since the professional development's purpose was to increase instructor's comfort with teaching engineering, rather than managing students who are learning engineering, these results are expected. It can be concluded that due to minimal change in responses between pre-test and post-test, teachers' personal belief in their ability to cope with a wide range of student behaviors during engineering activities was not significantly impacted.

Lastly, *outcome expectancy* is teachers' personal beliefs that their teaching of engineering is affecting the learning outcome of students [2]. This category consisted of 5 questions, with topics relating to effort and teaching style with regard to the students' achievements and overall outcome in engineering. A paired t-test between the pre-test and post-test of the 22 participants showed no statistically significant mean difference between the two, with a $p = 0.078$, and only a 4-point increase in minimum from pre-test to post-test resulting in little change for the average. The questions in this category were referring to a teacher's feelings about their own teaching styles and how that impacts students learning engineering. The lack of change is possibly due to confidence in individual teaching styles at baseline, which is indicative from the post-test results, and that the majority of teachers stayed confident in their ability to change student outcomes as a result of the way they teach. The workshop was also only three days long, primarily focused on understanding engineering and thinking like a student in order to most effectively implement the modules. Thus, another possibility is that teachers have not had ample opportunity or time to assess if they have changed or improved their ways of teaching engineering. A separate theory could predict that teachers feel the same about their effort level contributing to the success of students regardless of the topic they teach and thus going through the engineering professional development workshop did not change their outlook regarding if their effort correlated to student outcomes in engineering specific topics. To conclude, the results of this professional development training implies that there is no significant change in *outcome expectancy* in regard to teachers' personal belief that their teaching effectiveness and effort is affecting the learning outcome of students.

An overview of how each teacher's self-efficacy scores ranked for pre- and post-professional development training was calculated by summing the points for all 23 questions in the self-efficacy survey. Participants were able to attain a total possible maximum of 138 points; these results can be seen in Table 3. A paired t-test between the pre- and post- test of the 22 participants displayed a statistically significant mean difference between the two, with $p = 0.00015$ ($p<0.05$). This significance can conclude that participants displayed more confidence in their engineering content knowledge, instruction of engineering courses, engagement of students in engineering, as well as being able to manage engineering classrooms and have an increased effort to student achievement outcome ratio. Figure 3 shows that the minimum significantly increases from 59 to 90, and the box-and-whisker plot shifts up, with 6.32-point decrease in standard deviation, resulting in less variation between individual self-efficacy scores after the professional development was administered, than at baseline, indicating positive growth.

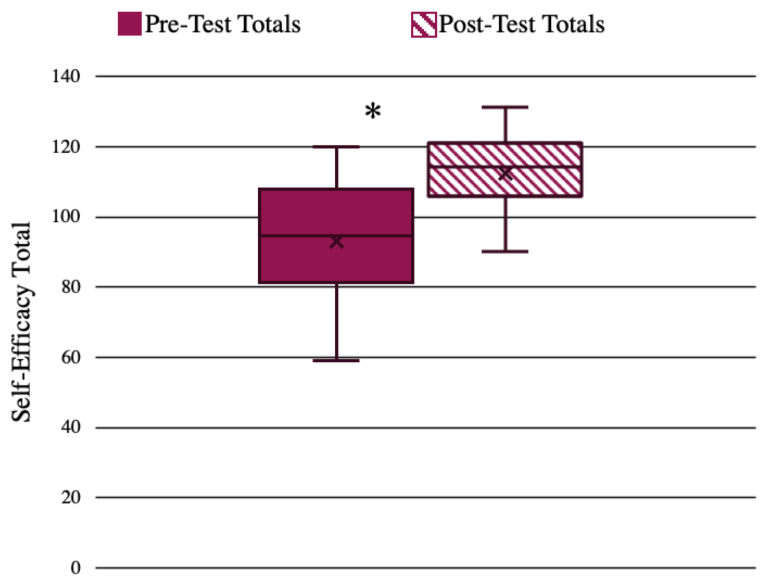

Figure 3—Self-efficacy individual totals. Total scores of all questions from self-efficacy pre-test and post-test represented as box-and-whiskers plots. The lower (Q1) and upper (Q3) quartile represent observations outside the 9-91 percentile range, the median is represented by the central line in the box, and x indicates the mean total self-efficacy score for participants. Data falling outside of the Q1-Q3 quartile are plotted as outliers of the data. * indicates statistical significance where p<0.001.

Teacher Satisfaction

Participating teachers were asked to complete an exit survey after the three-day professional development training that included free response questions relating to their experience at the professional development seminar. Out of the 22 attendees, 15 participated in the exit survey and gave an overall rating of 4.9/5 for their experience at the seminar. Figure 4 shows a summary of responses gathered from the survey.

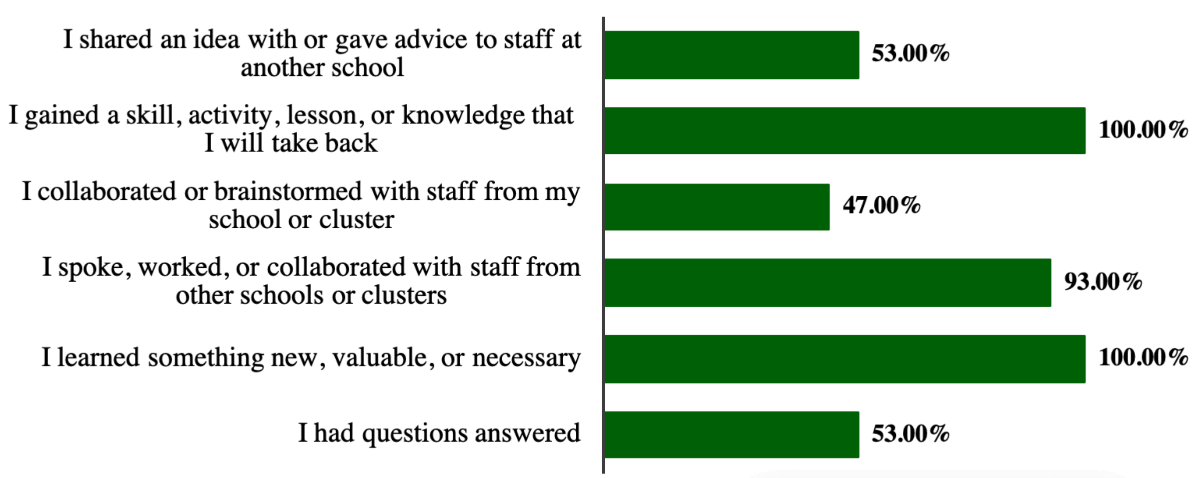

Figure 4—Teacher feedback regarding achievement at professional development seminars.

When asked what teachers learned during the professional development that they would apply within their work/school, the majority of the responses included addition of hands-on lessons and projects. Other responses included:

> "How to implement projects in my classroom that are useful and engaging to my students and that foster deeper connections"
>
> "How to make math fun for struggling students"
>
> "Use modules as alternative assessments"

Participants were also asked about their motivation to attend the professional development seminar, 5/15 teachers stated they wanted to learn more about STEM and how to incorporate it and bring awareness about it into the classroom, 3/15 responded saying it was due to compensation, and others reasoned it was to bring more hands-on and engaging activities to the classroom. Overall, there was a very positive response to the seminars, and 8/15 said the seminar needed no improvements, one stating "*It was one of the best trainings I have ever been to. Thank you.*" Some suggestions for future sessions included:

> "More moving around"
>
> "…include a short session on each day on networking, giving us time to make connections and share contact information with the other teachers that were in attendance…"

Overall, the participants rated the seminar a 4.9 / 5.0 and the majority enjoyed their time at the professional development seminar.

Conclusions and Recommendations

Increasing student interest in STEM careers is directly correlated to how these subjects are introduced. While increased interest is a nationwide priority, preparing students to succeed and affirming their understanding of such careers early on is arguably of higher importance. Teaching engineering related content and concepts is new for many K-12 math teachers who have not themselves been introduced or prepared to teach such content [25]. Creating professional development seminars that introduce current math teachers to engineering is the first step in that important process of preparing students to succeed. Teachers who participated in the three-day professional development seminar showed positive responses and increased growth in their knowledge and attitude with regards to self-efficacy in their ability to teach engineering topics. Many of the teachers showed promise towards implementing more engineering concepts and more hands-on activities in their current classrooms as they now felt more comfortable with the topics.

The professional development seminar in this study only assessed immediate and short-term progress of teacher self-efficacy. However, self-efficacy does not end at the completion of professional development seminars, but rather reaches into the classroom. It was evident by the results for topics such as outcome expectancy and disciplinary self-efficacy, that teachers need time to practice what they have learned and time to incorporate engineering topics and discussions within their classrooms to better evaluate their self-efficacy on such topics. Student outcomes is one such topic that is essential to determining overall sustainability and implementation of learned concepts. This study did not evaluate whether students benefited from expanding teachers' engineering knowledge and ability to convey that knowledge. Student understanding and overall knowledge on engineering was beyond the scope of the project. However, the respective teachers will be asked to participate in a follow-up TESS survey at the end of the academic year immediately following the PD, along with individual interview sessions to discuss the implementation process.

Ultimately, the effect of such professional development seminars on increasing student interest in and preparing them to pursue STEM careers is highly important. This plays out much like the domino effect: professional development given to teachers is shown to improve their confidence in teaching engineering and STEM related topics, leading to a better understanding of what these fields are and have to offer students. With increased confidence and understanding, teachers can more effectively convey that information to the students, which will ultimately create a better learning environment for the students. Similarly, students who have a better understanding of otherwise difficult concepts, are more likely to be excited about those subjects, and thus more likely to pursue related careers. While K-12 teachers regularly engage in required professional development that sometimes highlight various STEM careers, teachers need more opportunities that help them prepare their students for such careers. Similar to required professional development that professionals (e.g. engineers and doctors) take to stay up-to-date on current technology, K-12 teachers should be provided with resources that will help them be more up to date with new methods of teaching, helping them effectively teach and inform their students in the best way possible, especially as the societal needs and technology evolve and change. It will become critical to increase awareness and interest in these fast-paced fields so future students have the toolbox needed to succeed at the university level and beyond.

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