Self-Efficacy of Teaching Engineering:

Does TEK8 Help or Hinder?

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Abstract*—*Integrating engineering into K-12 classrooms is gaining considerable attention. With new standards, such as the Next Generation Science Standards (NGSS), that require the incorporation of engineering through design into the K-12 curriculum, it is essential that opportunities be provided to those teaching in K-12 to aid in appropriate integration. Translating Engineering Research to K-8 (TEK8) addresses this need through a summer research experience followed by a fall semester course that accomplishes K-12 outreach related to the research. While the course seems to increase interest related to integrating engineering into K-12 classrooms, we are interested in extending this analysis to understand impacts on self-efficacy. Specifically, we sought to answer the following research question, "How do participants' self-efficacy towards teaching engineering change over a semester?" To frame this investigation, we conceptualized self-efficacy as one's belief in their own ability to teach engineering design challenges in the K-12 context.

Keywords—self-efficacy; K12; engineering design

I. INTRODUCTION

In the world today, the importance of technology and engineering has increased the need for K-12 students to be involved in the next generation's needs. As such, an interest in these fields must be fostered from a young age in the hopes of creating engineers of the future [1]. However, many students are not equipped with the problem solving skills necessary to be successful in the engineering workforce. To combat this issue, many programs have been created to advance science, technology, engineering, and math education in the K-12 space [2]. These programs have produced positive outcomes beyond an interest in engineering and technology such as deeper, more meaningful student learning [3] and an appreciation of how learning done in the classroom can be applied to solve real-world problems [1].

In order to reach such outcomes, it is necessary to create an environment conducive to learning engineering concepts. For teachers, creating an engaging learning environment requires a strong sense of self-efficacy, which encompasses their confidence and belief in their ability to teach material [4]. In addition, this self-efficacy can be a major determinant in teachers' desire and effort to incorporate engineering concepts into curricula [5]. To have successful students, teachers must first be knowledgeable about engineering content. They must also be able to choose effective tools to deliver it [7]. In many cases, universities are not equipping teachers with the content knowledge needed to foster a strong self-efficacy in teaching engineering to K-12 students [6]. As such, one of the national priority areas for K-12 STEM education is STEM teaching preparation and professional learning [7]. Often times individuals who already have a high sense of engineering self-efficacy, such as engineers and engineering students, are less interested in working with K-12 students [8] and do not have the pedagogical skills to do so.

The Translating Engineering Research to K-8 (TEK8) program has been created in an attempt to address the lack of K-12 student interest in engineering through preparing classroom teachers and engineering underagraduate students to become better communicators and engineering career ambasadors. This work-in-progress paper reports the results of a self-efficacy survey administered to participants in the TEK8 program.

II. TEK8

A. History

TEK8 is currently in its 5th iteration. The first few iterations of the program are well documented in an American Society for Engineering Education Conference paper [11] and a European Journal for Engineering Education [9] journal article. As such, we only provide general highlights of the program.

As reported in an ASEE paper [11], the goals of TEK8 are to:

- Improve engineering career awareness at the K-8 grade levels.
- Introduce, and thereby encourage, underserved youth to consider engineering as a viable college/career pathway.
- Increase knowledge of, and experience with, the design process.
- Give engineering faculty, who want to have an impact in K-8, an effective outreach venue to accomplish broader impacts of their research in the university community.
- Give undergraduate engineering students an exposure to university research and potentially interest them in advanced study and/or research careers.
- Improve communication skills of engineering students (i.e., how to relate technical experiences to the general public and/or children) and instill in the students the desire to be ambassadors of their careers.

- Give in-service K-8 teachers the skills to facilitate open-ended projects with their students that teach the engineering design process, explain the societal impact of the projects, and use low-cost, everyday materials.

To achieve the above goals, during the first year of the TEK8 program, a cohort of undergraduate engineering students began the program by participating in a summer research experience in an engineering lab. These students were supported by funds provide by the faculty members running the lab (most often funding related to an NSF or similar project). During that experience, the students were fully immersed into a research lab environment to build foundational knowledge about an area of research similar to the experience students gain when participating in an NSF Research Experience for Undergraduate (REU). The following fall semester, those students then enrolled in the TEK8 course.

In the course, the engineering students were joined by a few practicing K-8 teachers who were interested in learning more about engineering design and integrating it into their classrooms. The undergraduate engineering students along with the teachers developed engineering design challenges based on the work the undergraduate students completed during the summer in their labs. These challenges were then administered in an after school program at a local middle school.

B. 2016 Cohort

While the goals of TEK8 have remained essentially the same, the program has evolved. The 2016 cohort, who are the focus for this paper, included a group of undergraduate engineering students who participated in a summer lab experience but also a group of teachers who participated in the summer lab experience as well. Both the undergraduate students and teachers completed a summer research experience together in the same lab to build their foundational engineering knowledge. They then participated as undergraduate student-teacher teams in the TEK8 course.

As facilitators of the program, we believed this shift in participation and potential for connection between the students and teachers merited further investigation. Subsequently, we decided to collect data related to self-efficacy to better understand both the students' and teachers' views on their ability to facilitate the engineering design process at the K-8 level.

III. Method

During the fall semester TEK8 course, a study was conducted to evaluate TEK8's ability to prepare teachers and engineering students to engage middle school students in an engineering focused after-school program. The study aimed to answer the following research question: How does participants' self-efficacy towards teaching engineering change over a semester?

Throughout the fall TEK8 course, undergraduate engineering students and teachers completed three administrations of the Teaching Engineering Self-Efficacy Scale [9]. The survey was comprised of 35 questions divided into 5 constructs as shown in table 1 and defined as follows. *Engineering content knowledge self-efficacy* is the teacher's personal belief in their knowledge of engineering that will be useful in a teaching context. *Motivational self-efficacy* is the teacher's personal belief in their ability to motivate students while teaching engineering. *Instructional self-efficacy* is the teacher's personal belief in their ability to teach engineering to facilitate student learning. *Engagement self-efficacy* is the teacher's personal belief in their ability to engage students while teaching engineering. *Disciplinary self-efficacy* is the teacher's personal belief in their ability to cope with a wide range of student behviors during engineering activites [12]. Cronbach's alpha was used to determine the reliability of each survey question in measuring the intended construct. Participants indicated their responses to each question using a 5-point Likert scale. The study was reviewed by an Institutional Review Board and determined as exempt since it was conducted in an established or commonly accepted educational setting.

TABLE I. TEACHING ENGINEERING SELF-EFFICACY SCALE CONSTRUCTS

Construct	**Number of Questions**	**Definition**
A	17	Engineering content knowledge self-efficacy
B	3	Motivational self-efficacy
C	5	Instructional self-efficacy
D	4	Engagement self-efficacy
E	6	Disciplinary self-efficacy

The survey was administered to both undergraduate engineering student and K12 teacher participants in the class at the beginning, middle, and end of the semester, labeled as round 1, 2, and 3 respectively. Seventeen participants took the surveys, where 14 were undergraduates and 3 were K12 teachers. For the purposes of this work-in-progress paper, we present the results of all 17 participants; however, we recognize there could be differences between the self-efficacy of the students and teachers. As we continue to analyze this data set and grow the program to include more teachers, we will investigate the differences between these groups. At this time since we have only 3 teachers, we did not separate them from the study for further investigation.

Each participant was given a numerical identifier which was then used during the analysis. The results of the survey were analyzed using descriptive statistics and parametric tests for significance, specifically an ANOVA and a post hoc pairwise comparison test. Both were used to examine whether enrollment in the program resulted in significant gains in self-efficacy between each of the 3 rounds.

There are limitations to the application of the results of the survey due to the small sample size and presence of incomplete surveys. In addition, due to the voluntary nature of the program, self-selection bias could be present in the results. While these items limit the generalizability of the findings, we believe the results provide useful information to further guide us in our analysis and implementation of TEK8.

IV. Results

A Chronbach's alpha was determined for each construct in round 1 in order to check the reliability of the instrument in this context. The results are presented in Table II. The survey questions used were all found to be reliable with the lowest Chronbach's alpha being 0.651 for questions within construct B and the highest being 0.933 for questions within construct E as seen below. The lower alpha value of 0.651 is considered acceptable significance [10]. It was found that the Chronbach's alpha for construct B would increase to 0.733 if the third question in the construct was deleted; however, since this construct only contained 3 questions to begin with, we decided to leave all 3 questions in the construct as [11] did in their development of the survey.

TABLE II. Round 1 Chronbach's Alpha by Construct

Construct	Chronbach's Alpha
A	0.910
B	0.651
C	0.700
D	0.698
E	0.933

Each round of the survey demonstrated an increase in overall mean self-efficacy score and a decrease in standard deviation as seen in Table III. The mean self-efficacy scores for each round by construct can be seen increasing in the Figure 1.

TABLE III. Self-Efficacy Scores by Round and Construct

Round	Construct	Mean	SD
1	A	3.512	0.986
	B	3.529	0.924
	C	3.376	0.951
	D	4.118	0.681
	E	3.520	0.931
2	A	4.103	0.672
	B	3.708	0.709
	C	3.907	0.694
	D	4.422	0.587
	E	3.844	0.785
3	A	4.623	0.533
	B	4.137	0.664
	C	4.412	0.642
	D	4.529	0.610
	E	4.049	0.837

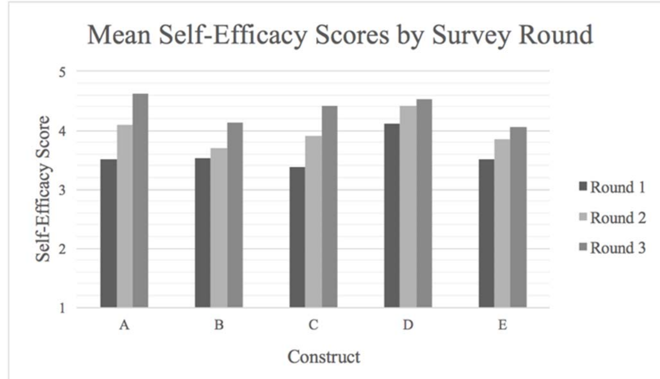

Fig. 1. *Self-Efficacy Scores*

The results of the survey show an overall increase in participants' sense of self-efficacy to engage K-12 students in engineering. The data was found to be parametric due to the normality of each of the five constructs. Normality was established using the skewness and kurtosis of each construct for each round. Due to the small sample size, a construct was considered normal if the skewness and kurtosis was within plus or minus the absolute value of 2. Only one construct in round 1 had a kurtosis outside of this range. Overall, the data was found to be normal.

An ANOVA, a parametric rank-based test, was used to determine if there was a statistically significant difference in survey scores between each of the three rounds for each construct. This test, in particular, was used because of its ability to check for significance between two or more groups of data. The ANOVA yielded p-values less than 0.05 for all of the five constructs confirming a significant difference in responses from each of the three survey rounds as seen in Table III.

A post hoc pairwise comparison test was used to further analyze the significance between each round (1 and 2; 1 and 3; 2 and 3) for each of the five constructs with significant p-values. The pairwise comparison test used is a parametric test that checks for statistically significant differences between two groups. The results of the test can be found in Table IV. In total, twelve out of the fifteen p-values found were less than 0.05. This confirms a significant difference in responses between the rounds for each comparison with a p-value less than 0.05. As this is a work in progress, future analysis will be done on correlations between qualitative and quantitative data in future publications.

TABLE IV. ANOVA Test by Construct

Construct	p-Value
A	0.000*
B	0.023*
C	0.000*
D	0.014*
E	0.009*

**Significant ($p < 0.05$)*

TABLE V. POST HOC PAIRWISE COMPARISON TEST P-VALUES BY CONSTRUCT

Construct	Round 1 & 2	Round 1 & 3	Round 2 &3
A	0.000*	0.000*	0.000*
B	0.557	0.014*	0.023*
C	0.001*	0.000*	0.003*
D	0.002*	0.019*	0.369
E	0.044*	0.015*	0.188

**Significant ($p < 0.05$)*

V. DISCUSSION

All of the self-efficacy constructs saw a significant change across the three rounds. In particular, all five constructs saw a significant change from round 1 to round 3. This suggests an overall increase in engineering teaching self-efficacy from the beginning of the semester to the end.

Deeper investigation into the survey instrument's five constructs has demonstrated changes over time for the TEK8 participants. From the beginning of the semester to its end, an overall increase in engineering teaching self-efficacy has been developed. The mean self-efficacy scores from each construct increased from round 1 to round 2 and from round 2 to round 3. These findings were also supported by the parametric tests for significance. Eighty percent of the constructs saw a significant difference in responses between the three rounds. Further investigation showed that all of the five constructs had significant differences for at least two out of the three round pairs (1 and 2; 1 and 3; 2 and 3). While we cannot prove causation between this increase in self-efficacy and participation in the TEK8 program, we do believe that TEK8 is providing opportunities for self-efficacy gains.

The increased self-efficacy gained can be used as a building block for the K-12 teachers when incorporating engineering concepts in their classrooms [5]. Over the course of the TEK8 program, participants reported higher levels of self-efficacy. With that information, they will be able to create an engaging learning environment that is conducive to students' understanding of engineering concepts [4]. In turn, we hope the students they are able to teach will have the opportunity to appreciate how engineering problem solving skills can help them solve real-world problems [1].

VI. FUTURE WORK

Since this is a work-in-progress paper, the analysis is not yet complete. We have documented our initial investigation into the findings, and we plan to further explore the effects of the program through qualitative interview data also collected from TEK8 participants (both undergraduate engineering students and K-12 teachers). With this data, we will be able to more fully understand our quantitative survey findings and make improvements to the program to ensure its effective growth. We also believe that the interview data will help us understand the unique differences between the students' and teachers' experiences since we could not pull out those differences in the quantitative results.

Another avenue of future work is to collect data from the students who participate in the after school program and from the students who are in the classrooms of the teachers. At this time, we hope that the experience teachers gained during TEK8 translates into engineering efficacy in their classrooms, but further investigation is needed to confirm.

VII. CONCLUSION

In conclusion, TEK8 seems to have made a positive impact in supporting participants' self-efficacy to teach engineering at the K-12 level. All three constructs demonstrated positive increasing trends with construct A (engineering content knowledge self-efficacy) having the largest mean score gains (1.111 points). At the end of TEK8 participants felt more confident in their engineering content knowledge.

VIII. ACKNOWLEDGMENTS

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