Board 117: WIP: Impact of Teaching Engineering Summer Academy on Teacher Efficacy and Teaching Beliefs

Dr. Joni M Lakin, Auburn University

Joni M. Lakin, Ph.D. from The University of Iowa, is Assistant Professor of Educational Foundations, Leadership, and Technology at Auburn University. Her research interests include educational assessment, educational evaluation methods, and increasing diversity in STEM fields.

Ms. Mary Lou Ewald

Mary Lou Ewald is the Director of Outreach for the College of Sciences and Mathematics at Auburn University. She is also the Co-PI for AU-AMSTI and the Director of the AU Science in Motion program. Prior to her current position, she served as a Science in Motion physics specialist and an Instructor of general biology courses at Auburn University. For the past 15 years, Ms. Ewald has specialized in K-12 educational program development and implementation and currently oversees an outreach staff that delivers over twenty STEM-based student programs annually, including BEST Robotics, Science Olympiad, Greater East Alabama Regional Science and Engineering Fair, Summer Science Institute, Auburn Mathematical Puzzle Challenge, AU Explore, and Science Matters. In recent years, she has focused her K-12 efforts on working with STEM faculty to create teacher professional development opportunities related to project-based learning in middle and high school classrooms. Her academic training includes a B.S. in Physics and an M.S. in Biology, both from Auburn University.

Nancy Nowlin Blanco, Project Lead the Way

Nancy Blanco currently serves as Alabama's Director of School Engagement for the STEM education non-profit Project Lead The Way (PLTW). Prior to joining PLTW, Nancy was the Lead English as a Second Language Teacher and PLTW Program Coordinator in Lee County Schools. Nancy earned her undergraduate degree from Auburn University and holds a Master of Education from the University of Alabama at Birmingham. She is currently pursuing her Ph.D. in Education from Auburn University.

Dr. Jessica A Gilpin, Auburn University

WIP: Impact of Teaching Engineering Summer Academy on Teacher Efficacy and Teaching Beliefs

Acknowledgements

We would like to thank Dr. Charles Eick for his contributions to the project that led to this work. We also gratefully acknowledge Auburn University's Office of the Vice President for University Outreach for funding this research.

Abstract

This WIP paper reports the first year's evaluation of a program where elementary teachers were trained to implement Project Lead The Way Launch modules in a summer STEM Academy for grades K-6. The goal of this project was to understand how the experience of teaching an informal STEM program influenced teachers' confidence for teaching STEM in their formal classroom. We used a combination of quantitative surveys and qualitative analysis of focus groups and individual teacher interviews to explore teachers' self-efficacy for teaching STEM and the benefits teachers observed for themselves and their students from participating in the program.

Early positive science and engineering experiences are believed to prime students for more success and interest in STEM fields in later education [1-3]. Unfortunately, elementary educators are the least likely to have positive associations with science and engineering or to have the preparation or confidence to teach STEM lessons in their classrooms [4-6]. This study reports the findings of a four-week, school-based Summer Engineering Academy that was targeted to low-income and English learners in a public school system in Alabama. In-service teachers served as informal STEM educators during the program, receiving professional development on the curriculum, and then leading the four-week program with groups of 5-15 students in rising grades 1-8. The focus of this research is on the changes in self-efficacy experienced by the teachers with respect to teaching science, teaching engineering, and using technology in the classroom. Quantitative surveys of teaching self-efficacy were augmented by teacher focus group interviews. In the coming academic year, additional interviews will explore how their summer teaching experience impacts their teaching practice or attitudes towards STEM in their classroom during the school year.

Research has consistently shown that elementary level teachers are less likely to feel confident about teaching science, mathematics and engineering concepts compared to other content areas [4, 5]. Part of this effect seems to be a lack of early, positive science experiences [6] and professional development (PD). To respond to this lack of confidence and sparse implementation of STEM lessons in elementary schools, a number of curricula and PD programs have been developed [7-11].

Guskey [12] made a provocative argument that most teacher PD had the incorrect assumption that you needed to change teacher attitudes to change their classroom practices and ultimately student learning outcomes. Therefore, PD focused on these attitudes and motivating teacher change. What Guskey argued was that PD should focus on changing teacher practices. Once practices changed, the attitudes and beliefs needed to sustain change would result from implementation (especially firsthand experience of positive student experiences), not the initial training. This is represented in Figure 1.

The framework of this study follows Guskey's model. If teachers successfully implement STEM programming, it can positively impact their beliefs and attitudes about their ability to teach STEM in their formal classroom by giving them the opportunity to see students learn and thrive. By having teachers implement the program in an informal setting first, they can enact new behaviors and observe students' learning without jeopardizing their formal classroom environment (or their own self-concept as a classroom teacher). We believe this lowers the sense of risk for teachers and allows those who would otherwise lack the confidence to try teaching STEM and specifically the Engineering Design Process.

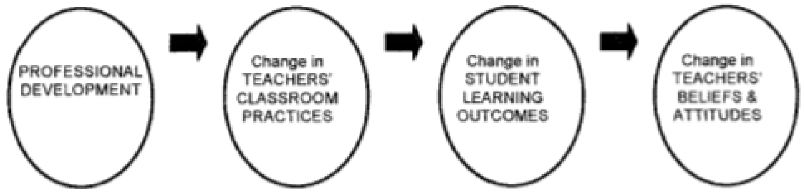

Figure 1. Figure from Guskey[12], “A model of teacher change”

This WIP paper reports the first year’s evaluation of a program where elementary teachers were trained to implement Project Lead The Way (PLTW) “Launch” modules in a summer STEM Academy for grades K-6. The goal of this research was to understand how the experience of teaching an informal STEM program influences teachers’ confidence for teaching in their formal classroom. We used a combination of quantitative surveys, classroom observations, and qualitative analysis of focus groups to explore the following research questions:

1. How did teachers’ self-efficacy for teaching engineering, teaching science, and using technology in the classroom change as a result of professional development and teaching a summer STEM academy?
2. What benefits did teachers observe for themselves and their students from participating in the program?
3. In a six-month follow-up, do teachers report changes in their teaching as a result of the summer experience?

Methods

This study was conducted in the context of a four-week Summer Engineering Academy held at seven elementary schools and one middle school in a county school system in Alabama that is a mix of rural and suburban towns. Students mostly ranged from rising first to sixth grade with a small number of rising 7th/8th students. Over 400 students were served by this program in Summer 2018. The two primary goals of the Summer Engineering Academy were: 1) Provide elementary teacher professional development that increases teacher self-efficacy and positive attitudes towards hands-on STEM instruction, and 2) Increase elementary student educational engagement and interest with STEM concepts and activities, particularly with underserved populations. To meet the latter goal, students who were English learners or eligible for Free or Reduced Lunch (FRL) were targeted for participation. One school had over 50% EL students, while others had nearly 100% students who were eligible for FRL.

The content of the academy was based on the PLTW "Launch" curricula for younger grade levels (K-5). PLTW is a widely used K-12 STEM curriculum that integrated project and problem-based learning and teaches the engineering design process and scientific inquiry process through its curricula. It is also aligned to the Next Generation Science Standards (NGSS).

Three weeks before the start of the summer program, the 44 in-service teachers attended Project Lead the Way Launch Classroom Teacher Training (CTT). This in-depth professional development experience is required of all teachers before they receive full access to the PLTW Launch program materials. All teachers completed the required online prerequisite components of the training before the first day of in-person professional development. The three primary objectives of the PLTW Launch Classroom Teacher Training are as follows:

> "Teachers will…
>
> 1) Develop an understanding of the activity-, project-, problem-based (APB) instructional approach, core to all 24 PLTW Launch modules.
>
> 2) Embrace their role as a facilitator of learning.
>
> 3) Gain familiarity with grade-level modules and experience how to plan and implement PLTW Launch modules in the classroom."

Teachers attain these objectives during by participating in collaborative discussions, experiencing hands-on activities from PLTW Launch Modules, and by answering reflective assignment questions, which are graded by the teacher trainers. Upon successful completion of all three assignments on day two, the teachers receive a certificate of PLTW Launch CTT completion and gain full access to course materials.

After training, teachers led a classroom of 5-15 students in a specific module from the Launch program. A few teachers had aides or student teachers, but most taught students on their own. These curricula are designed for formal instruction, but were adapted for use in this informal environment. For example, teachers arranged lessons and activities into a program that met for four hours on four days of the week. They adjusted the schedule and exploration time based on their professional judgment. As part of our evaluation of the program, we gathered a wide variety of data from the teachers and students.

Sample

A total of 41 teachers participated in the professional development training and then taught in the Summer Engineering Academy. Among these 41 teachers, seven were not academic teachers during the school year; one being a P.E. teacher, one,a special education teacher, two were contract tutors for the schools, and three were retired. Of the 34 other teachers, half expected to teach in a self-contained classroom in the coming year (typical of lower elementary grades) and the other half expected to teach in a collaborative setting (specializing in specific content areas).

In our sample, 34% of the teachers reported holding a bachelor's degree (some with additional graduate credits); 34% held a master's degree; 12% held a Specialist degree; and just 1 (2%) held a doctorate. Seventy percent of teachers were female. Nine of the teachers identified as African

American, one identified as Asian, and 31 reported being White. Teachers ranged in experience from 0 to 29 years of teaching experience (three were incoming teachers), with an average of 11.8 years of teaching experience (SD = 9.4).

Only five of the participating teachers had previously participated in any form of STEM professional development. Three of these teachers had led a robotics or STEM Challenge program in their schools, while one taught engineering in their classroom, reporting that in his/her classroom, “we have created catapults and elevators.”

Assessments

As part of our evaluation of the program, we gathered a wide variety of data from the teachers. One survey included was the Teaching Engineering Self-Efficacy Scale (TESS)[13] which includes 23 questions on a 1-6 Likert type scale (strongly agree to strongly disagree). One example item is “I can explain the different aspects of the engineering design process.” This scale was designed to have subscales. However, given the strong internal consistency, we used only the total score.

We also administered the “Science Teaching Efficacy and Beliefs” scales and “Student Technology Use” scales from the Teacher Efficacy and Attitudes toward STEM Survey (T-STEM) [14]. The science scale includes 11 items on a 1-5 Likert type scale (strongly agree to strongly disagree). An example item is “I am confident that I can explain to students why science experiments work.” The technology scale includes 8 items on the same scale. An example item is “[My students] use technology to communicate and collaborate with others, beyond the classroom.” We confirmed that the three scales had adequate internal consistency at each time point (α= .92 to .93 at pretest, α=.89-.98 at post1, α= .93-.95 at post2). See Table 1.

Table 1. Internal Consistency of Scales

	Pre-test (1)	Post-test (2)	Follow up post (3)
Engineering	.93	.94	.95
Science	.92	.89	.94
Technology	.93	.98	.93

At the end of the camp, we used focus group interviews to further explore teacher perceptions of the program and its impacts on themselves and their students. The general protocol included the following questions:

1. How comfortable did you feel teaching this STEM program? What specific areas do you think you could have used more support?
2. What was the overall level of student interest and engagement during the four-week STEM academy? Did the level of interest and engagement change over depending on the type of activity? Explain.
3. If you had English learners in your classroom, how engaged were they with the tasks and activities? Which activities more engaged? Which activities less engaged?
4. What from this program will impact your teaching in the classroom? Give an example.
5. What suggestions would you make for improvements next year?

In December, 2018, around six months after the program, teachers were contacted again. Response rates were low (9 out of 41), so analyses of the efficacy scales are not included here. However, the responding teachers provide a glimpse into the changes that they have made that they attribute to their summer experiences. We asked "How have you carried over your summer experience to your formal classroom?" and provided the following options which were drawn from the focus group findings:

Asking more open ended questions to students
Allowing students more time to answer questions
More group projects
More group discussions
More training for students in collaboration skills
Added more activities that relate to science or engineering
Introduced an engineering design project I hadn't used before
More effective in my science teaching

More confident in my science teaching
Started a robotics or STEM club
No changes to my teaching

Analyses

We used a repeated measures ANOVA to look at the change in scores on each of the three self-efficacy measures. Focus group interviews from all eight sites were transcribed and coded for common themes related to teachers' comfort with STEM, their perceptions of student gains, and their own learning experiences. A follow up survey was distributed in December, 2018, asking teachers to complete the efficacy scale one more time and to report what changes they have made to their teaching as a result of their summer experience. Descriptive statistics from that survey are also reported.

Results

RQ1: Gains in Teaching Self-Efficacy

We used a repeated measures ANOVA to look at the change in scores on each of the three self-efficacy measures separately. We found that all three efficacy scales showed significant increases from pre to post-test at the PD workshop. All had large effect sizes. Once the academy started, engineering and science teaching self-efficacy maintained their levels through the post-summer survey. However, technology self-efficacy dropped following the summer program (pairwise comparison, $p < .05$). See Table 2 and Figure 1.

Table 2. Repeated Measures ANOVA of Efficacy Scores

		M	SD	Std. Error	95% Confidence Interval	Effect of Time: Wilks' λ	F (2,21)	p	Partial η^2
Engineering	Pre-training	4.00	0.74	0.15	3.68 - 4.32	0.247	32.048[b]	<.001	0.753
	Post-training	5.02	0.58	0.12	4.77 - 5.27				
	Post-teaching	5.04	0.45	0.09	4.84 - 5.23				
Science	Pre-training	3.45	0.69	0.14	3.15 - 3.74	0.397	15.932[b]	<.001	0.603
	Post-training	4.09	0.39	0.08	3.92 - 4.26				
	Post-teaching	4.00	0.78	0.16	3.67 - 4.34				
Technology	Pre-training	3.23	0.80	0.17	2.88 - 3.57	0.391	16.384[b]	<.001	0.609
	Post-training	4.04	1.07	0.22	3.58 - 4.51				
	Post-teaching	3.19	0.72	0.15	2.88 - 3.50				

Teaching Engineering Efficacy ***Teaching Science Efficacy*** ***Technology for Teaching Efficacy***

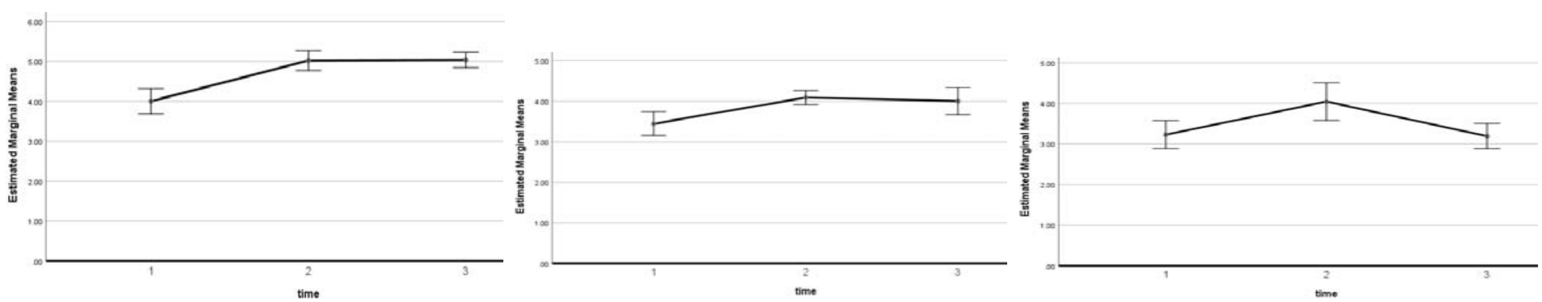

Figure 1a-c. Changes in efficacy from pre-training (1) to post-training (2) and post-academy (3). Note that TEE was scaled 1-6 while the other were 1-5.

RQ2: Teacher Perceptions of Their Learning and Student Learning

At the end of the four-week program, the evaluation team conducted focus groups with program teachers. Based on these questions, teachers provided a wide variety of comments and feedback for the program. In addition, we gained insights into what they learned as teachers, what they learned about their students, and what they observed their students learning. The following is an outline of the themes identified from the seven focus groups with representative quotations:

What the Students Learned

1. **Understanding knowledge in the context of inquiry.** Students stopped expecting there to be right and wrong answers:

   "At first I got a lot of questions. I told them to go back to the group and come up with a solution. They weren't used to that. They wanted me to give them the answer! They learned to do it and stretch themselves. I feel like they learned the content more."

2. **Students were responsible for their own learning:**

   "Students are the experts now"
   "I *can't* answer all the questions"
   "They learned critical thinking and working well together to troubleshoot and problem solve"

3. **Students learned how to evaluate and discuss a problem** (especially younger students [insert age range? 1-2 grade?), older students [grade 5-8?] learned to critically evaluate their models

   Teacher has to "ask like 50 or more questions to get them going"

   One solution was to have K/1 students verbally explain a design rather than write it (or use that to lead to written explanation)

   "They would finish the projects in their quickly. In the group that excelled…. what I was able to do is take them back to the design model and say go and test it and see if it works.. What improvements could you make to it? It was incredible how they can innovate. They were able to understand and make improvements."

4. **Students learned to collaborate and work well in groups**

   One teacher described scaffolding group collaboration for younger grades. She had each student draw their solution, tell their group about it, identify something they like in each design, the plan a group design using pieces they liked from each individual design.

Students learned to collaborate and not just “jostle and compete” with team mates.

5. **Students learn perseverance and to keep trying and solving problems**

   Teachers with low ability students said their students gained confidence when they were able to completely rebuild their prototype in a day; students “had pride in hard work.”

   Students learned that there’s not always a right and wrong answer, they have to try it.

   Students learned to solve real problems; “engineers don’t give up!”

What the Teachers Learned and Plan to do in the future

1. **How teachers plan to change their teaching as a result of this experience**
   - Use more exploration
   - More time in small groups, collaborating
   - Have students teach each other
   - Give students more “think time” and allow them time to figure out problems on their own
   - Plan to let go of control more, let students learn from their mistakes
   - More coding in the classroom, more “Project Based Learning” (PBL)
2. **Increased appreciation of their students**

   “I value students’ discussion and contributions more.” The students gained confidence in contributing to the discussion over time.

   “Students are able to accomplish things that I thought they were not capable of.”

   Teachers of younger students were especially impressed. One teacher explained that she felt more confident in letting younger students explore and figure things out: [While exploring magnets] “They discovered a lot of the things I was supposed to teach them next.”
3. **Teachers learned it was OK for them not to have the answers all the time**

   “It’s OK if I step back.”
   “Try it and see!”
   “Sometimes I felt like there’s nothing for me to do. I learned to release control.”
   “Was hard not to jump in at first.”
   “It is difficult for all teachers to quash their inner control freak. They want to give it all out, “here it is”, “do like this.”
   “Learn to let students go and accomplish.”
4. **Hands on learning was noted to be especially helpful for less able students**

   One teacher plans to add a “genius hour” for her special ed classroom with investigative learning.

   Less able students learned more about simple machines from the hands on activities.

RQ3: Followup

During the school year, we wanted to quickly assess if the teachers noted any changes to their formal teaching practice as a result of the summer experience with informal STEM. We created a checklist of potential changes based on the themes and responses we received to the focus groups about how teachers thought they might incorporate what they learned into their classrooms.

As Table X shows, the most common changes were asking more open-ended questions to students, using group discussions and projects, and allowing students more time to formulate responses to teacher questions. Many teachers had reported learning to use these strategies more (and gaining confidence in their questioning) during the academy focus groups as well. Several also reported introducing new STEM activities, even robotics clubs, in the current year.

Our response rate was poor, with just nine teachers responding who also had complete pre/post data. However, even if only these nine teachers made any changes, that means over 20% of teachers report changes to their teaching that benefit their students.

Table 3. Teacher reported changes in teaching practices (N=9)

Changes to teaching	Percent reporting
Asking more open ended questions to students	67%
Allowing students more time to answer questions	89%
More group projects	67%
More group discussions	78%
More training for students in collaboration skills	44%
Added more activities that relate to science or engineering	44%
Introduced an engineering design project I hadn't used before	44%
Started a robotics or STEM club	11%
More effective in my science teaching	22%
More confident in my science teaching	22%
No changes to my teaching	0%

Scientific or scholarly significance of the study or work

This program offered a unique opportunity to study the experiences of teachers learning about engineering in the context of teaching in a low-stakes, informal, summer teaching context. Informal learning environments are especially interesting and rich learning opportunities for teachers, but their impact on teacher development and practices has not been studied in depth.

These environments offer a low-stakes environment to explore new methods of teaching. This is in comparison to the high stakes in the regular classroom where teachers may be hesitant to risk changing their standards methods of teaching and risk not meeting student learning outcomes and accountability.

Summary

Our quantitative survey results showed significant increases in efficacy for teaching engineering and science as well as in using technology in teaching during PD. Once the academy started, engineering and science teaching self-efficacy maintained their levels while technology self-efficacy dropped following the summer program. One potential explanation for this decline is that teachers struggled to use the technology during the program. In our classroom observations, we noted that some classrooms struggled to get technology to work (specifically, tablets used for videos and some games failed to load) or to keep the class on-task with the tablets (e.g., noise from games, retrieving/retuning tablets to charging station). These negative experiences were also reflected in the focus groups, where teachers felt that technology was more useful to older students who used tablets for coding and watching videos that helped them solve technical issues in building robots. They felt tablets in particular ended up distracting more than helping younger students. These experiences may explain the decline in confidence teachers expressed.

The continued gains in science and engineering teaching self-efficacy were also supported by the focus group data. Teachers were enthusiastic in their reflections on the program. They felt that students were capable of much more creativity and critical thinking than they were previously aware of. They expected they would allow students more time to engage in discussion and more think time for answering questions. This was also reflected in our fall follow-up, where a majority of teachers reported using these practices more often in their formal classroom

Conclusions

Contrary to what Guskey[12] might predict, our teachers did show substantial growth in their teaching efficacy from the professional development experience, which was mostly maintained after the Summer Academy. However, this study does lend some support to Guskey's idea that teachers must enact curriculum before their core attitudes and beliefs will change. Focus group findings indicated that teachers realized substantial benefits to themselves and their students as a result of leading a Summer Academy classroom. The PD was not sufficient for their learning and the hands-on experience gave them new insights into teaching. In our follow up, they also reported translating these new skills and beliefs to their formal classroom.

From this Summer Academy experience, teachers gained firsthand knowledge of the potential for student inquiry and group-based problem solving. The teachers also realized their own potential for relaxing control of their classroom, raising their potential for fostering true scientific inquiry and engineering design processes in their formal classroom environments. As a result, this study suggests that informal STEM experiences are a potentially valuable professional development activity for elementary teachers to enhance their STEM teaching and efficacy.

References

[1] N. DeJarnette, "America's children: Providing early exposure to STEM (science, technology, engineering and math) initiatives," *Education,* vol. 133, no. 1, pp. 77-84, 2012.

[2] A. V. Maltese and R. H. Tai, "Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students," *Science Education,* vol. 95, no. 5, pp. 877–907, 2011.

[3] P. s. C. o. A. o. S. a. Technology, " Prepare and inspire: K-12 education in science, technology, engineering and math (STEM) for America's future," Executive Office of the President, Washington, DC2010.

[4] K. Appleton, "How do beginning primary school teachers cope with science? Toward an understanding of science teaching practice," *Research in Science Education,* vol. 33, no. 1, pp. 1–25, 2003.

[5] R. R. Buss, "Efficacy for teaching elementary science and mathematics compared to other content," *School Science and Mathematics,* vol. 110, no. 6, pp. 290-297, 2010.

[6] O. S. Jarrett, "Science interest and confidence among preservice elementary teachers," *Journal of Elementary Science Education,* vol. 11, no. 1, pp. 49-59, 1999.

[7] L. S. Nadelson, J. Callahan, P. Pyke, A. Hay, M. Dance, and J. Pfiester, " Teacher STEM perception and preparation: Inquiry-based STEM professional development for elementary teachers," *The Journal of Educational Research,* vol. 106, no. 2, pp. 157-168, 2013.

[8] C. T. Forbes and E. A. Davis, "The development of preservice elementary teachers' curricular role identity for science teaching," *Science Education,* vol. 92, no. 5, pp. 909-940, 2008.

[9] E. A. Davis and J. Smithey, "Beginning teachers moving toward effective elementary science teaching," *Science Education,* vol. 93, no. 4, pp. 745-770, 2009.

[10] D. DiFrancesca, C. Lee, and E. McIntyre, "Where is the "E" in STEM for young children?," *Issues in Teacher Education,* vol. 23, no. 1, pp. 49-64, 2014.

[11] A. E. Adams, B. G. Miller, M. Saul, and J. Pegg, "Supporting elementary pre-service teachers to teach STEM through place-based teaching and learning experiences," *Electronic Journal of Science Education,* vol. 18, no. 5, pp. 1-22, 2014.

[12] T. R. Guskey, "Professional development and teacher change," *Teachers and Teaching: theory and practice,* vol. 8, no. 3, pp. 381-391, 2002.

[13] 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," *Journal of Engineering Education,* vol. 103, no. 3, pp. 463-485, 2014.

[14] F. I. f. E. Innovation, *Teacher Efficacy and Attitudes Toward STEM Survey*. Raleigh, NC: Author, 2012.