With the inclusion of engineering in the Next Generation Science Standards ([NGSS], NGSS Lead States, 2013) and in many adopted state science standards (Lopez & Goodridge, 2018), K-12 teachers must be prepared to incorporate engineering into their science teaching. Further, the national emphasis on preparing children for careers in science, technology, engineering, and mathematics (STEM) domains has resulted in K-12 teachers from multiple disciplines being called upon to incorporate engineering into their teaching. The relationship between teaching efficacy and teaching effectiveness has been widely explored and research suggests that teachers who have higher efficacy in an area employ more diverse teaching methods, persist in their teaching, and are more likely to have students who learn (Jerald, 2007; Shaughnessy, 2004). Because efficacy is context specific and because the link between teaching efficacy and student learning has been documented in multiple contexts, it will be important to explore teaching efficacy and its relationship to student learning in the area of engineering education. Professional development opportunities have been reported to increase inservice teachers' engineering teaching efficacy and STEM content knowledge (Author, 2019a). Rural teachers, however, have cited a lack of access to STEM focused professional development (PD), university resources, and peers to bounce ideas off of as barriers to rural STEM teaching (Goodpaster, Adedokun, & Weaver, 2012). Providing rural teachers access to STEM PD and exploring the impacts of that PD on engineering teaching efficacy, will be important for moving the field forward. The purpose of this study is to begin this exploration by identifying the personal engineering efficacy and engineering teaching efficacy of rural in-service teachers before and after participating in a two-day engineering-focused PD program. More specifically, we sought to answer the following research questions:

1. What impact does participating in a summer professional development focused on the

engineering applications of mathematics and science have on rural K-12 science and mathematics teachers' personal engineering efficacy and engineering teaching efficacy?

2. What do rural teachers perceive to be barriers to implementing engineering in their classrooms and how do those barriers change after participating in professional development?

Related Literature

The current work was guided by a conceptual framework consisting of effective PD and efficacy. We employed Bandura's (1977) self-efficacy theory when developing the PD activities to ensure we were providing teachers with mastery experiences in applying math and science concepts to engineering. In the following sections we provide overviews of the literature related to efficacy and PD.

Efficacy

Self-efficacy refers to an individual's belief in their ability to succeed in a specific situation (Bandura, 1977). According to Bandura (1977), self-efficacy consists of two dimensions – efficacy expectation and outcome expectancy – and is influenced by mastery experiences, vicarious experiences, verbal persuasion, and emotional and psychological states. Teacher efficacy, an extension of self-efficacy, refers to a teachers' belief in his/her ability to influence student learning (Guskey & Passaro, 1994). Grounding their work in Bandura's two dimensions of self-efficacy, Gibson and Dembo (1984) developed the teaching self-efficacy scale (TES), which consisted of two subscales – general teaching efficacy and personal teaching efficacy. Teacher efficacy, like self-efficacy is situation dependent and will vary across contexts such as grade level, subject matter being taught, and student characteristics (e.g., ability level, socioeconomic status, English language learner) (Tschannen-Moran, Woolfolf Hoy, & Hoy, 1998). For example, a 1st grade teacher may have very high teacher efficacy in the area of teaching word decoding but very low teacher efficacy in the area of science instruction. Likewise, a high school Physics teacher may have high teacher efficacy in the area of photonics but low teacher efficacy in the area of cellular reproduction. The context-specific nature of teacher efficacy led to the development of instruments to measure efficacy in specific content areas such as science (e.g., Enochs, Riggs, & Ellis, 1993; Riggs & Enochs, 1990), mathematics (e.g., Enochs, Smith, & Huinker, 2000), and engineering (Yoon, Evans, & Strobel, 2014).

Research has shown that teacher efficacy is a strong indicator of how successful a teacher will be in the classroom (Cakiroglu, Capa-Aydin, & Woolfolk Hoy, 2012). Extensive research has been conducted regarding teachers' science and mathematics teaching efficacy (Bleicher, 2004; Ginns, Tulip, Watters, & Lucas, 1995; Gresham, 2008; Morrell & Carroll, 2010; Swars, Daane, & Giesen, 2006;), and since the recent development of the Teaching Engineering Efficacy Scale (TESS; Yoon et al., 2014), studies related to teachers' engineering teaching efficacy are beginning to surface in the literature (Coppola, 2019; Fogg-Rogers, Lewis, & Edmonds, 2017; Author, 2017; Author, 2019a). In a statewide study of Oklahoma elementary teachers, Author (2017) found teachers scored themselves lowest in engineering pedagogical content knowledge self-efficacy (KS), slightly higher in engineering outcome expectancy (OE), and relatively high in the areas of engineering engagement self-efficacy (ES) and engineering disciplinary self-efficacy (DS). This indicates teachers in the study felt more comfortable in their abilities to engage students and manage their classrooms during engineering lessons but were much less comfortable with their pedagogical content knowledge of how to identify and deliver engineering lessons. A few studies have utilized TESS scores to determine the impacts of engineering-focused training on engineering teaching efficacy (Coppola, 2019; Fogg-Rogers et al., 2017; Author, 2019a). Author (2019a) found that elementary teachers' overall engineering teaching efficacy as well as their KS, DS, and OE increased significantly after participating in a multiple day engineering-focused professional development. Coppola (2019) reported an increase in pre-service elementary teachers' KS, DS, and ES after completing a course in which they first engaged in engineering units as students and later developed and taught an engineering unit to K-5 students. Likewise, Fogg-Rogers and colleagues (2017) found pre-service teachers' engineering teaching efficacy increased after participating in training over the engineering design process and teaching engineering lessons to children in after school programs. Similarly, Smetana, Nelson, Whitehouse, and Koin (2019) explored a field-based undergraduate course incorporating various engineering experiences to help prepare elementary pre-service teachers to integrate engineering within their classrooms. Their findings indicated that pre-service teachers showed increases in KS, DS, and ES scores over the course of the program. The authors concluded that keys to the success of this approach included capitalizing on partnerships; immersing candidates as learners in various educational settings with expert educators; providing opportunities to observe, enact, and analyze the enactment of high-leverage instructional practices; and incorporating opportunities for independent and collaborative reflection.

Professional Development (PD)

There is a rich literature supporting the need for STEM professional development in K-12 education as well as for researching PD approaches and their effectiveness in education settings. Numerous studies have reported that participating in engineering-focused PD can increase teachers' engineering content knowledge (Duncan, Diefes-Dux, & Gentry, 2011; Macalalag et al., 2010;), understanding of engineering design (Yoon, Diefus-Dux, & Strobel, 2013), and teaching efficacy (Gardner, Glassmeyer, & Worthy, 2019; Author, 2019a). Goodnough, Pelech, and Stordy (2014) employed action research to investigate PD aimed at enhancing STEM integration in elementary school settings. This was motivated by research which suggests that PD that does not provide relevant, contextual, and collaborative opportunities are often experienced by teachers as being ineffective. The study authors suggest a need to consult with PD participants before, during, and after the PD to maximize effectiveness. Their study also reinforces other conclusions from literature that the nature of effective PD should enhance not only the teachers' competence, but also, and perhaps more-importantly, their confidence in teaching engineering.

These, and numerous other reports on PD effectiveness, have led to the development of a few engineering specific PD models. Donna (2012) presents one such PD model designed to foster engineering pedagogy and STEM integration through six successive stages: (a) exploring prior knowledge related to engineering and the relationships between different domains, (b) developing basic knowledge of engineering, (c) engaging in cooperative engineering design, (d) reflecting on the design activity as both learners and educators, (e) extending knowledge and connections between different domains, and (f) continuing PD through professional learning communities (PLCs). This model focuses on improving both teachers' basic and pedagogical content knowledge via cooperative engineering design activities, reflection, sense-making and continuing development via PLCs. The author argues that research-informed PD in engineering design pedagogy can foster integrated and effective STEM education approaches.

Further, the Boston Museum of Science's Engineering is Elementary (EiE) program PD providers articulate the following best practices following five years of PD implementation experiences: (a) engaging participants in hands-on, active learning experiences, (b) placing participants as learners to promote perspective building and confidence for implementing activities in their own classrooms, (c) modeling effective pedagogical strategies during workshop activities, (d) utilizing formative assessment to determine participants' prior-knowledge and provide context for workshop facilitators, (e) providing participants with foundational knowledge to frame the workshop activities, (f) utilizing the student hat, teacher hat approach to allow participants to transition from learners to practitioners, (g) engaging in group work and discussion, (h) offering time for reflection and debriefing over activities, and (i) providing time for participants to plan future classroom implementation (Sargianis, 2012).

More recently, Reimers, Farmer, and Klein-Gardner (2015) conducted a thorough review of the literature, including Donna's (2012) aforementioned work, and created the Standards for Preparation and Professional Development for Teachers of Engineering. According to Reimers et al. (2015) all engineering-focused PD activities should (a) address the fundamental nature of engineering, (b) build participants' engineering pedagogical content knowledge, (c) present engineering design and problem solving as a context for teaching standards in other content areas (e.g. science, mathematics, reading), (d) empower teachers to identify appropriate instructional resources and assessment tools, and (e) be aligned to research on teaching and learning.

While the aforementioned PD models articulate the desired qualities of STEM PD, they stop short of specifiying a specific duration for PD. Much of the work focused on the impacts of integrated STEM PD, however, reports on long-term PD programs that last multiple weeks or months (Brown & Bogiages, 2019; Ring, Dare, Crotty, & Roehrig, 2017). While engaging in sustained PD is arguably important, many rural teachers lack access to such opportunities due to their remote locations, lack of available funding resources, and low relevance of urban or suburban focused PD on the needs of rural communities (Lovally, 2018). Further, limited rural broadband access can constrain opportunities to engage in prolonged virtual PLCs.

Methods

Program Description

Teaching Engineering Applications in Math and Science (TEAMS) is a professional development workshop facilitated by the College of Engineering at a large university in a geographically large, predominately rural, northwestern state. The program has been running since 2010 with extramural sponsorship from various foundations. The two-day TEAMS workshop aims to facilitate integration of engineering within K-12 curricula by engaging K-12 teachers with university engineering and education faculty to improve understanding of the diversifying engineering profession, as well as develop unique approaches to engage their students in engineering. Each year, the workshop travels to two different locations to allow for teachers from different regions of the state to attend. After a four-year hiatus, the program reconvened in 2019 with a new faculty team. To aid with overall program development and long-term planning, the faculty decided to treat the 2019 workshop as a pilot and initiated a formal assessment of participating teachers' personal engineering efficacy, as well as engineering teaching efficacy before and after the workshop using validated survey instruments and open-ended questions. The goal of this pilot year assessment was to determine the impacts of TEAMS activities on participating teachers and to inform the development of future workshop activities.

Overview of professional development activities. The first day of the PD consisted of (a) pre-assessments, (b) 45 minutes of introductions and team building activities, (c) two 90 minute engineering design learning activities lead by engineering faculty, and (d) a 90 minute session focused on identifying the connections between the day's engineering activities and national mathematics and science standards. The second day of the PD consisted of (a) two 90 minute engineering learning activities lead by engineering faculty, (b) a two hour long session focused on designing problem based learning units, and (c) post-assessments. The four engineering sessions are briefly described below:

1. Civil Engineering – This session introduced participants to how to calculate buoyancy and its application to civil engineering. Participants were required to calculate the density of a golf ball and determine how many golf balls a particular boat design could hold.
2. Electrical Engineering – This session introduced participants to wave properties and how they are used by electrical engineers. During the session, participants completed various activities to measure wavelength, frequency, and amplitude and were introduced to different ways that engineers utilize those measurements in their work.
3. Biomechanical Engineering – This session introduced participants to scientific and mathematic concepts used by biomechanical engineers when they design assistive devices to aid patients with physical movement. Participants built and tested vertical jumping machines.
4. Chemical Engineering – This session had participants reflect on their knowledge of energy and sustainability, and introduced basics of common energy sources, forms and conversions, as well as environmental implications. Participants engaged in energy conversion demonstrations including a simple pendulum, a bicycle-powered electric generator, foaming polyurethane insulation, and a solar-powered hydrogen fuel cell car educational kit.

Each of the engineering sessions was designed to incorporate mathematics and science content with different engineering contexts. To accomplish this, each session began with the engineer covering the mathematics and/or science content required to understand the specific engineering context. For example, the civil engineer spent 60 of the 90 minutes teaching mathematics concepts related to buoyancy. Then, the engineer discussed the broader utility of those concepts and introduced an engineering activity – using the concepts to estimate a prototypical boat's maximum payload. Further, to promote relevance for rural teachers, each engineer presented engineering contexts related to their research at the state's land grant institution – research that addresses challenges and opportunities from local and rural to national and global.

The education sessions focused on how to design problem based learning units by identifying and unpacking the math and/or science standard(s) to be covered, identifying an engaging engineering context, and developing instructional activities aimed at building students' knowledge and skills necessary to understand the engineering context and master the standard. The teachers were encouraged to work in self-determined groups and engage with the university faculty to design their own units.

Participants. Thirty K-12 teachers enrolled in TEAMS, however only data from the 19 who completed both the pre and post assessment and provided consent are included in the study. Demographic information for study participants is presented in Table 1. **Insert Table 1**

Measures

Participants completed the TESS (Yoon et al., 2014), the Engineering Design Self-efficacy Instrument ([EDSI] Carberry, Lee, & Ohland, 2010), the Design, Engineering and Technology Instrument ([DET] Yasar, Baker, Robinson Kurpius, Krause, & Roberts, 2006) and various demographic related questions. Participants responded to survey items via Qualtrics prior to completing the TEAMS workshop and again at the end of the workshop.

Teaching Engineering Self-efficacy Scale, TESS. The TESS, developed to measure K–12 teachers' efficacy related to teaching engineering (Yoon et al., 2014), is a 23-item instrument with a 6-point Likert scale ranging from strongly disagree (score of 1) to strongly agree (score of 6). The instrument consists of four subscales: (a) Engineering Pedagogical Content Knowledge Self-efficacy (KS, nine items, Cronbach's $\alpha = 0.96$), which measures teachers' beliefs in their personal knowledge of engineering that will be useful for teaching engineering; (b) Engineering

Engagement Self-efficacy (ES, four items, Cronbach's α = 0.93), which measures teachers' beliefs in their ability to engage students while teaching engineering; (c) Engineering Disciplinary Self-efficacy (DS, five items, Cronbach's α = 0.92), which measures teachers' beliefs in their ability to manage student behaviors during engineering activities; and (d) Engineering Outcome Expectancy (OE, five items, Cronbach's α = 0.89), which measures teachers' beliefs that teaching has an impact on students' learning of engineering. The mean score for each subscale may range from 1 to 6 (Yoon et al., 2014).

Engineering Design Self-efficacy Instrument, EDSI. Carberry et al., (2010) developed the EDSI to measure individuals' self-concepts related to engaging in engineering design tasks in each of the following four construct areas: self-efficacy, motivation, outcome expectancy, and anxiety. For the current study, only the self-efficacy subscale was used. Carberry et al. (2010) reported a Cronbach's α value 0.97 for the self-efficacy subscale. Each subscale included nine 11-point Likert questions with a scale ranging from 0 to 100 with higher scores indicating greater efficacy (Carberry et al, 2010). The first question of each EDSI subscale, labeled EDSI engineering design (EDSI ED), is designed to measure an individual's self-concept toward conducting engineering design. Questions 2–9 of each subscale, labeled EDSI engineering design process (EDSI EDP), are designed to measure an individual's self-concept related to each step of the Massachusetts Department of Education (MDOE) engineering design process. The steps in the MDOE design process include: identify a design need, research a design need, develop design solutions, select the best possible design, construct a prototype, evaluate and test a design, communicate a design, and redesign.

Design, Engineering, and Technology Survey, DET. The DET was developed by Yasar et al. (2006) and later re-evaluated by Hong, Purzer, and Cardella (2011). The 5-point Likert instrument was designed to measure teachers' perception of engineering and familiarity with teaching engineering, engineering design, and technology. The re-evaluated instrument contains 40 items that explained 74% of the variance and loaded on four factors – Importance of DET (19 items, α = 0.91), Familiarity of DET (8 items, α = 0.81), Stereotypical Characteristics of Engineers (7 items, α = 0.77), and Barriers to Integrating DET (6 items, α = 0.68). The current study used only the Barriers to Integrating DET subscale from the revised instrument.

Data Analysis

Responses to each questionnaire were analyzed using the statistical software program R (R Core team, 2020). Due to evidence of a non-normal structure of the residuals for each of the six fitted models (TESS and EDSI subscales) and the relatively small sample size ($n = 19$), nonparametric analysis was used. The Wilcoxon procedure was chosen because the data are paired, the differences in scores appear roughly symmetric around the median, and one teacher's responses should have no impact on the other. A Bonferroni multiple correction factor was implemented to account for the potential inflated Type I error rate.

After examining the scores descriptively, we noticed that there were differences in preworkshop scores when comparing participants who taught science with those who did not as well as differences for those who had previously integrated engineering and those who had not. Further, we sought to assess whether teaching science and incorporating engineering had a statistically significant impact on survey scores. To do so, we calculated a change score for each of the 19 respondents using the following formula:

$$\frac{Post\ Score_i - Pre\ Score_i}{Pre\ Score_i}$$

i from 1 – 19 respondents

This change score was used as the response for analysis. Due to the non-normal structure of the residuals across each of the six multiple linear regression models with small sample sizes across the different combinations of covariates, a permutation approach was considered to analyze these data. Based on further visual exploration of the raw data, it appears that there is not enough evidence for concern that the distributions of the change scores are vastly different, nor is there alarming evidence of unequal variances across the combinations of covariates. Although we will proceed under these assumptions, it should be noted that the small counts in observations make these assumptions difficult to truly assess. The starting full models include the following for each TESS and EDSI survey, totaling six unique models:

$$Change\ Score_{ij} = Science_i * Engineering_j + Science_i * Pre\ Score + Engineering_j * Pre\ Score + \epsilon_{ijk}$$

$$\text{ith Science group} \begin{bmatrix} 1\ if\ taught\ Science \\ 0\ if\ not\ taught\ Science \end{bmatrix}$$

$$\text{jth Engineering group} \begin{bmatrix} 1\ if\ incorporated\ Engineering \\ 0\ if\ not\ incorporated\ Engineering \end{bmatrix}$$

Each respondent's pre score was included in the model to account for their initial score when assessing change. An F-statistic was calculated from a full 2 way interaction model for each of the three interaction terms and compared to 10,000 permutated F-statistics calculated under the assumption that the combinations of Science, Engineering, and pre score has little impact on change score. Each were calculated by shuffling the change scores of the 19 respondents to new combinations within the design matrix, and re-fitting the current model. Because there are multiple unique tests being performed across the TESS and EDSI, we used a Bonferroni correction factor to account for an inflated Type I error rate.

The DET responses were explored visually, as some scores are reverse coded and as we felt it would be inappropriate and misleading to uniquely test the 10 individual items separately.

Results

Descriptive statistics for all tests are presented in Table 2. To determine the internal consistency of the subscales, Cronbach's α values were calculated prior to subscale analysis. Pretest Cronbach's α values were TESS Pedagogical Content Knowledge, α =0.78, TESS

Engagement, α = 0.93, TESS Disciplinary, α = 0.90, TESS Outcome Expectancy, α = 0.97, EDSI EDP, α = 0.95, and Barriers to DET, α = 0.72. Posttest Cronbach's α values were TESS PCK, α = 0.90, TESS Engagement, α = 0.92, TESS Disciplinary, α = 0.82, TESS Outcome Expectancy, α = 0.70, and EDSI EDP α = 0.95. **Insert Table 2**

Wilcoxon tests indicate evidence for positive increases in multiple self-efficacy subscale scores from pre to post workshop. This included an increase in participants' (a) TESS KS score from pre (*Mdn* = 4.00) to post workshop (*Mdn* = 5.00), $W = 6$, $Z= 3.527$, $p = 0.003$, and large effect $r = 0.808$; (b) EDSI ED score from pre (*Mdn* = 50.00) to post workshop (*Mdn* = 70.00), $W = 0$, $Z = 3.775$, $p = 0.002$, and large effect size $r = 0.87$; and (c) EDSI EDP score from pre (*Mdn* = 45.00) to post workshop (*Mdn* = 70.00), $W = 0$, $Z = 3.805$, $p = 0.001$, and large effect size $r = 0.87$. The TESS ES showed some evidence of a pre to post change ($W = 9.5$, $Z = 2.341$, $p = 0.076$, $r = 0.537$), although each yielded a median score of 5.0.

When analyzing impacts of teaching science or incorporating engineering into a teacher's classroom, participants were assigned to one of four subgroups – those who teach science, those who did not teach science (nonscience) , those who have incorporated engineering, and those who have not incorporated engineering (nonengineering). Subgroup analysis showed little to no statistical evidence of pre/post shifts on the TESS or EDSI scores. The TESS and EDSI, much like other Likert scale instruments, may suffer from a ceiling effect which may inhibit detection in actual change. Further, the small sample sizes across the categories of teachers provide a low power statistical analysis, making it difficult to detect pre/post changes. Despite a lack of evidence of statistical change, we did identify notable differences in change scores when we examined the data descriptively and visually (Figures 1 and 2). Change scores represent the difference in pre and post scores as a percentage of the prescore. For example, a change score of

0.25 indicates that the post score is 25% higher than the pre score and a change score of -1.25 indicates that the post score was 125% lower than the prescore. All median TESS KS change scores were positive, with the largest changes being for nonscience teachers and nonengineering teachers. While science and engineering teachers saw no change in median scores from pre to post for TESS ES, nonscience and nonengineering teachers scores increased. Both EDSI factors showed positive median change across all teachers, with nonscience teachers exhibiting greater change than science teachers and nonengineering teachers exhibiting greater change than engineering teachers. **Insert Figures 1 and 2**

Prior to the workshop, participants listed lack of equipment, lack of time for teacher learning, lack of teacher training, and lack of teacher knowledge as the most highly rated barriers to integrating engineering, with each of those barriers receiving a mean score of at least 3.0 on a 4.0 scale. By the end of the workshop, only two barriers received a mean score of at least 3.0 – financial support and equipment. Due to the small sample size, we chose to be cautious when examining change scores, only focusing on scores that changed by at least 20%. Over the course of the workshop, only five barriers changed by at least 20%: (a) lack of teacher training decreased by 26%, (b) lack of teacher knowledge decreased by 31%, (c) lack of time for teachers to learn engineering decreased by 21%, (d) lack of administrative support increased by 37%, and lack of financial support increased by 21%. **Insert Table 3**

At the time of the pretest, science teachers listed most DET items as weaker barriers than nonscience teachers and engineering teachers listed most DET items as weaker barriers than nonengineering teachers. The amount of pre to post change for each group was similar (within 20%) for all but three DET items. First, change scores for emphasis on engineering in district curriculum were much larger for nonscience teachers (-0.30) than for science teachers (0.03) and higher for engineering teachers (-0.21) than nonengineering teachers (0.05). Second, change scores for lack of financial support were much larger for science teachers (0.28) than for nonscience teachers (0.06) and higher for engineering teachers (0.36) than nonengineering teachers (0.08). Finally, change scores for lack of administrative support were higher for nonengineering teachers (0.50) than for engineering teachers (0.24).

Discussion

Over the course of the two-day program, participants' personal engineering design efficacy increased, as indicated by evidence from Wilcoxon tests. This was expected as each of the four engineer-led sessions directly involved participants in engineering design activities, which are analogous to Bandura's mastery experiences (Bandura, 1977). TESS results were mixed, with strong evidence for participants' engineering pedagogical content knowledge efficacy (KS) increasing, some evidence for engineering engagement efficacy (ES) increasing, but little evidence of changes seen in outcome expectancy (OE) or disciplinary efficacy (DS). The lack of change in DS was not surprising as participants entered the program with high efficacy levels related to managing their classrooms, thus there was not much room for growth. The lack of evidence of a change in OE for the entire group was also not surprising given that it is linked to things outside of a teacher's control, such as students' prior knowledge and family support. Studies employing subject matter teaching efficacy instruments have reported similar findings for OE (Coppola, 2019; Deehan, 2017). The very large gains in KS indicate that participants felt workshop activities were effective in helping them acquire content knowledge related to engineering as well as pedagogical strategies for teaching that engineering content knowledge to students. Although, the gains in ES were not statistically detected as different, it is important to note that nonscience and nonengineering teachers had much higher change scores for TESS ES than science and engineering teachers, indicating that participants who were less familiar with science inquiry and engineering design-based teaching methods at the start of the PD left the program feeling more able to engage students in engineering learning opportunities. Also of note was the significant increase in participants' EDSI scores. The authors are unaware of prior studies that examine changes in EDSI scores for K-12 teachers, however, the preassessment EDSI scores for this study are consistent with Authors (2017) findings.

Initally, TEAMS participants reported lack of time for teacher learning, lack of teacher training, and lack of teacher knowledge to be significant barriers to implementing engineering, which is consistent with the findings of Author (2019b). Further, many of the reported barriers decreased over the course of TEAMS, though we lacked the power to detect significance. Similarly, Yoon et al. (2013) found that elementary teachers who participated in an engineeirng PD program exhibited decreased DET barriers scores, though the change was not significant. Many of the barriers to teaching engineering that decreased over the course of the TEAMS PD were those that could be considered to be within teacher control (i.e., teacher knowledge, teacher training, time for teacher learning), while those that did not decrease could be considered outside of teacher control (i.e., administrative support, financial support, lack of student knowledge). The barrier that showed the greatest change from pre to post was that of administrative support. During the first day of the workshop, when one of the facilitators was introducing the math and science standards to the participants, the group went on a bit of a tangent about administrative control over what was taught in their buildings. An important aspect of teachers' professional learning is the opportunity to learn from one's peers. This is often lacking in rural schools (Lovally, 2018), so the TEAMS facilitator let the conversation flow organically to allow these rural teachers to engage in valuable dialogue that they might not otherwise be able to. The teachers spent roughly 20 minutes discussing the unique teaching challenges they faced due to local control over curriculum. This conversation, likely led to the sharp increase in administrative support being listed as a barrier. At the end of the PD, the barriers that were listed as the most prevalent were lack of financial support and equipment. The TEAMS faculty made an effort to present low cost activities, however, there were some demonstrations teachers may have considered to be too costly to implement, such as hydrogen fuel cell cars. The hydrogen fuel cell car was meant as an extra learning tool for teachers and not something that had to be implemented to teach the topic to students. Additionally, while the activities presented to the participants can be implemented for less than $100, given the limited resources that schools must work with, that $100 would likely come from the teachers' pockets. Many teachers receive low wages, so spending $100 of their personal income could create undue financial hardship.

Discipline Taught

While the limited sample size prevented us from discerning evidence of statistical differences between different subgroups, it is interesting to note that science teachers started out with higher engineering pedagogical content knowledge efficacy, higher engineering engagement efficacy, and higher personal engineering design process efficacy than nonscience teachers. This could be due to the alignment between scientific inquiry teaching methods and problem based teaching methods that are often seen when implementing engineering design challenges with youth. When examining difference in DET scores, it was noted that change scores for lack of emphasis on engineering in district curriculum indicated that nonscience teachers reported a much larger change in this area than science teachers. For the study participants, engineering was included in their state standards for science but not for other content areas. As such, nonscience teachers may have perceived lack of emphasis as a greater barrier at the start of the PD because it was not a part of the standards that they were required to teach. This could account for the greater level of change seen in nonscience teachers.

Experience Teaching Engineering

Approximately half of participants had used engineering activities in their classrooms prior to attending TEAMS. It is not surprising that on the presurvey those who had taught engineering listed lack of teacher knowledge as a weaker barrier than those who had no prior engineering teaching experience. As with nonscience teachers, nonengineering teachers began the program listing lack of emphasis on engineering in district curriculum as a much larger barrier than nonengineering teachers. In fact, nonengineering teachers' mean prescores were a full point higher than engineering teachers' prescores.

Limitations and Future Research

This study was limited to a small number of participants from a single state who self-selected into a summer PD program and therefore cannot be used to make broad generalizations. Further, the study made use of self-reported measures in a pre/post format which could have introduced bias. Future research with larger, more diverse participants, and varied data sources will be important for expanding upon the current findings. Moreover, we did not follow study participants to see if/how they implemented activities into their classrooms. Additional work should examine the relationship between personal engineering efficacy and engineering teaching efficacy and the ways in which participants implement workshop activities into their teaching. Resulting impacts on student learning and attitudes toward engineering should also be explored.

Conclusions

This study provides evidence that short duration professional developments that focus on integrating mathematics and/or science with engineering can enhance rural K-12 teachers' personal engineering efficacy and engineering teaching efficacy. This work makes an important contribution because much of the current literature examines the impacts of extended PD programs on teacher learning (Brown & Bogiages, 2019; Ring et al., 2017). While longterm professional learning opportunities are certainly valuable and likely preferred, these types of learning experiences are often limited in rural and remote locations where teachers are faced with geographic isolation and finacial limitations (Lovalley, 2018). Literature focused on the specific impacts of short-term, intensive integrated STEM PD for rural teachers is lacking, making this work an important contribution.

Further, this study expands upon the research literature on rural STEM PD in two meaningful ways. First, rural spaces are often associated with small sample sizes that make powerful quantitative analysis difficult. We were able to detect evidence of pre to post changes while employing very conservative nonparametrics analysis and correction factors. While we were unable to inferentially examine the change between subgroups, we feel our work adds value to the field through our use of visualizations and descriptive statistics to examine these change scores between groups. Waiting until multiple rounds of data collection occurs to establish large enough samples to allow for the level of power needed to test multiple subgroups could take years. This is not feasible for researchers and PD providers who need to make data based decisions after each implementation. Through visual and descriptive exploration of the data, we were able to successfully discern meaningful differences in the way subgroups responded to our program and can now use that information to make improvements to future PD offerings. This is in line with Smith and Little's (2018) argument that many very meaningful advances in psychology came about from small-N studies.

Second, this study found that allowing participants to engage in engineering design challenges based on local engineering research was effective at boosting personal engineering efficacy and pedagogical content knowledge efficacy related to engineering. The importance of connecting instruction to local places is prevalent in the literature (Gruenewald, 2008), particulary for rural science instruction (Avery, 2013). There is a great need for research focused on connecting place-consious pedagogy with engineering instruction at the K-12 level. This study begins to address this issue by showing that engaging in local engineering challenges can enhance teacher efficacy. Still, there is a need for more focused research on how teachers can connect their local context to engineering challenges that can be used to teach the science and nonscience standards that they are already covering in their locally mandated curriculum. It will be important to further investigate the specific types of PD experiences teachers from different disciplines might need as well as identify ways to help teachers make more deliberate connections between engineering and the content they already teach.

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Table 1

Participant demographics

	Number	Percentage		Number	Percentage
Gender			*Years Teaching Experience*		
Male	6	32	0-5	3	16
Female	13	68	6-10	4	21
			11-15	6	32
Ethnicity			16-20	2	10
White	18	95	Over 20	4	21
More than One	1	5			
Grade Level			*Subject taught*		
K-6	4	21	Math only	4	21
6-8	6	32	Science only	5	26
7-12	2	10	Math and science	8	43
9-12	7	37	Engineering	1	5
			Other (gifted coordinator)	1	5

Table 2

Descriptive Statistics for Teaching Engineering Self-efficacy Scale (TESS) and Engineering Design Self-efficacy Instrument (EDSI), and Barriers to Integrating Engineering Subscale Items of the Design Engineering Technology Instrument by Time

	Time									
	Pre workshop					Post workshop				
	M	SD	Min	Max	Mdn	M	SD	Min	Max	Mdn
TESS KS	3.92	0.66	2.67	5.00	4.00	4.81	0.60	3.56	5.89	5.00
TESS OE	4.23	1.00	1.00	6.00	4.20	4.53	0.49	3.60	5.40	4.60
TESS ES	4.67	1.29	1.00	6.00	5.00	5.22	0.65	4.00	6.00	5.00
TESS DS	5.07	0.66	4.00	6.00	5.00	5.02	0.60	4.00	6.00	5.00
EDSI ED	42.11	27.40	0.00	90.00	50.00	71.58	11.68	50.00	90.00	70.00
EDSI EDP	45.72	21.47	0.00	88.75	45.00	69.08	15.46	28.75	90.00	70.00
Teacher training	3.05	0.91	1.00	4.00	3.00	2.26	0.81	1.00	3.00	2.00
Teacher knowledge	3.11	0.94	1.00	4.00	3.00	2.16	0.76	1.00	3.00	2.00
Time to integrate	2.79	0.85	1.00	4.00	3.00	2.52	0.77	2.00	4.00	2.00
Time for teacher learning	3.11	0.94	1.00	4.00	3.00	2.47	0.77	1.00	4.00	2.00
Emphasis on engineering	2.84	1.11	1.00	4.00	3.00	2.53	0.84	1.00	4.00	2.00
Administrative support	1.58	0.77	1.00	3.00	1.00	2.16	0.69	1.00	4.00	2.00
Student math skills	2.21	0.79	1.00	4.00	2.00	2.42	0.77	1.00	4.00	2.00
Student reading skills	1.89	0.88	1.00	4.00	2.00	2.16	0.69	1.00	3.00	2.00
Financial support	2.53	1.12	1.00	4.00	2.00	3.05	0.85	2.00	4.00	3.00
Equipment	3.11	1.11	1.00	4.00	4.00	3.05	0.85	2.00	4.00	3.00

Note. KS = engineering pedagogical content knowledge self-efficacy; OE = outcome expectancy; ES = engineering engagement self-efficacy; DS = engineering disciplinary self-efficacy; ED = engineering design self-efficacy; EDP = engineering design process

Table 3

Descriptive Statistics for Teaching Engineering Self-efficacy Scale (TESS) and Engineering Design Self-efficacy Instrument (EDSI), and Barriers to Integrating Engineering Subscale Items of the Design Engineering Technology Instrument by Teaching Discipline and Previous engineering Teaching Experience

	Science (n = 13)				Not Science (n = 6)			
	Pre workshop		Post workshop		Pre workshop		Post workshop	
	Mean	Mdn	Mean	Mdn	Mean	Mdn	Mean	Mdn
Teacher training	2.77	3.00	2.08	2.00	3.67	4.00	2.67	3.00
Teacher knowledge	2.92	3.00	2.15	2.00	3.50	4.00	2.17	2.00
Time to integrate	2.77	3.00	2.38	2.00	2.83	2.50	2.83	2.50
Time for teacher learning	2.92	3.00	2.31	2.00	3.50	4.00	2.83	2.50
Emphasis on engineering	2.38	2.00	2.46	2.00	3.83	4.00	2.67	3.00
Administrative support	1.62	1.00	2.15	2.00	1.50	1.00	2.17	2.00
Student math skills	2.15	2.00	2.38	2.00	2.33	2.00	2.50	2.50
Student reading skills	1.92	2.00	2.23	2.00	1.83	1.50	2.00	2.00
Financial support	2.46	2.00	3.15	3.00	2.67	3.00	2.83	2.50
Equipment	2.92	3.00	3.00	3.00	3.50	4.00	3.17	3.50
	Engineering (n = 9)				Not Engineering (n = 10)			
	Pre workshop		Post workshop		Pre workshop		Post workshop	
	Mean	Mdn	Mean	Mdn	Mean	Mdn	Mean	Mdn
Teacher training	2.67	3.00	1.89	2.00	3.40	4.00	2.60	3.00
Teacher knowledge	2.56	3.00	1.89	2.00	3.60	4.00	2.40	2.50
Time to integrate	2.56	3.00	2.33	2.00	3.00	3.00	2.70	2.00
Time for teacher learning	2.89	3.00	2.00	2.00	3.30	3.50	2.90	3.00
Emphasis on engineering	2.33	2.00	2.44	2.00	3.30	4.00	2.60	2.50
Administrative support	1.78	2.00	2.22	2.00	1.40	1.00	2.10	2.00
Student math skills	2.22	2.00	2.67	3.00	2.20	2.00	2.20	2.00
Student reading skills	2.11	2.00	2.44	2.00	1.70	1.50	1.90	2.00
Financial support	2.44	2.00	3.33	3.00	2.60	2.50	2.80	2.50
Equipment	2.78	3.00	2.89	3.00	3.40	4.00	3.20	3.50

Note. KS = engineering pedagogical content knowledge self-efficacy; OE = outcome expectancy; ES = engineering engagement self-efficacy; DS = engineering disciplinary self-efficacy; ED = engineering design self-efficacy; EDP = engineering design process

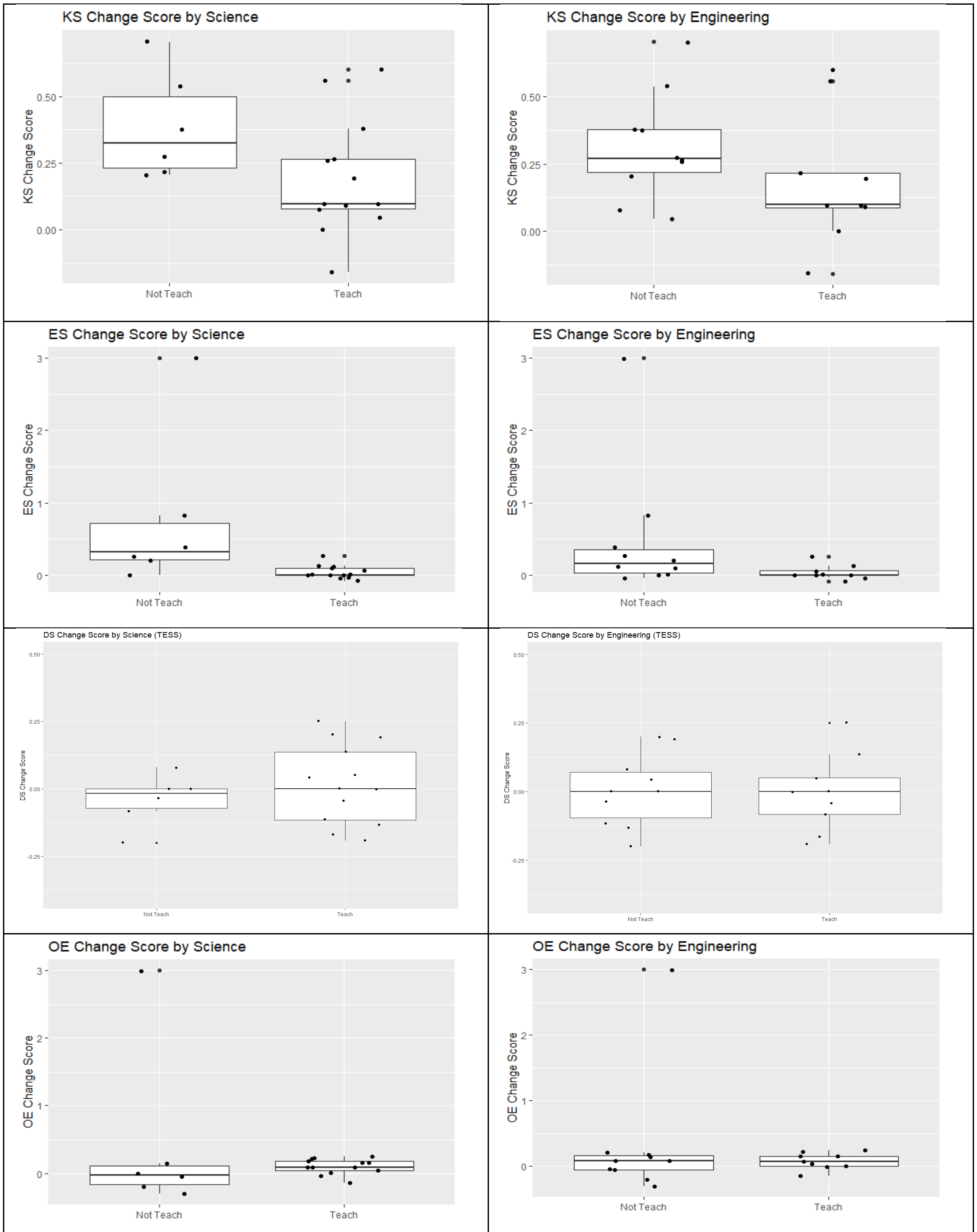

Figure 1. Box an wisker plots of change scores ((postscore-prescore)/prescore) for Teaching Engineering Self-Efficacy Scale (TESS). Plots on the left are dissagregated by whether or not participants teach science. Plots on the right are disaggregated by whether or not partiicpants have previously taught engineeirng activities. KS = engineering pedagogical content knowledge self-efficacy; OE = outcome expectancy; ES = engineering engagement self-efficacy; DS = engineering disciplinary self-efficacy.

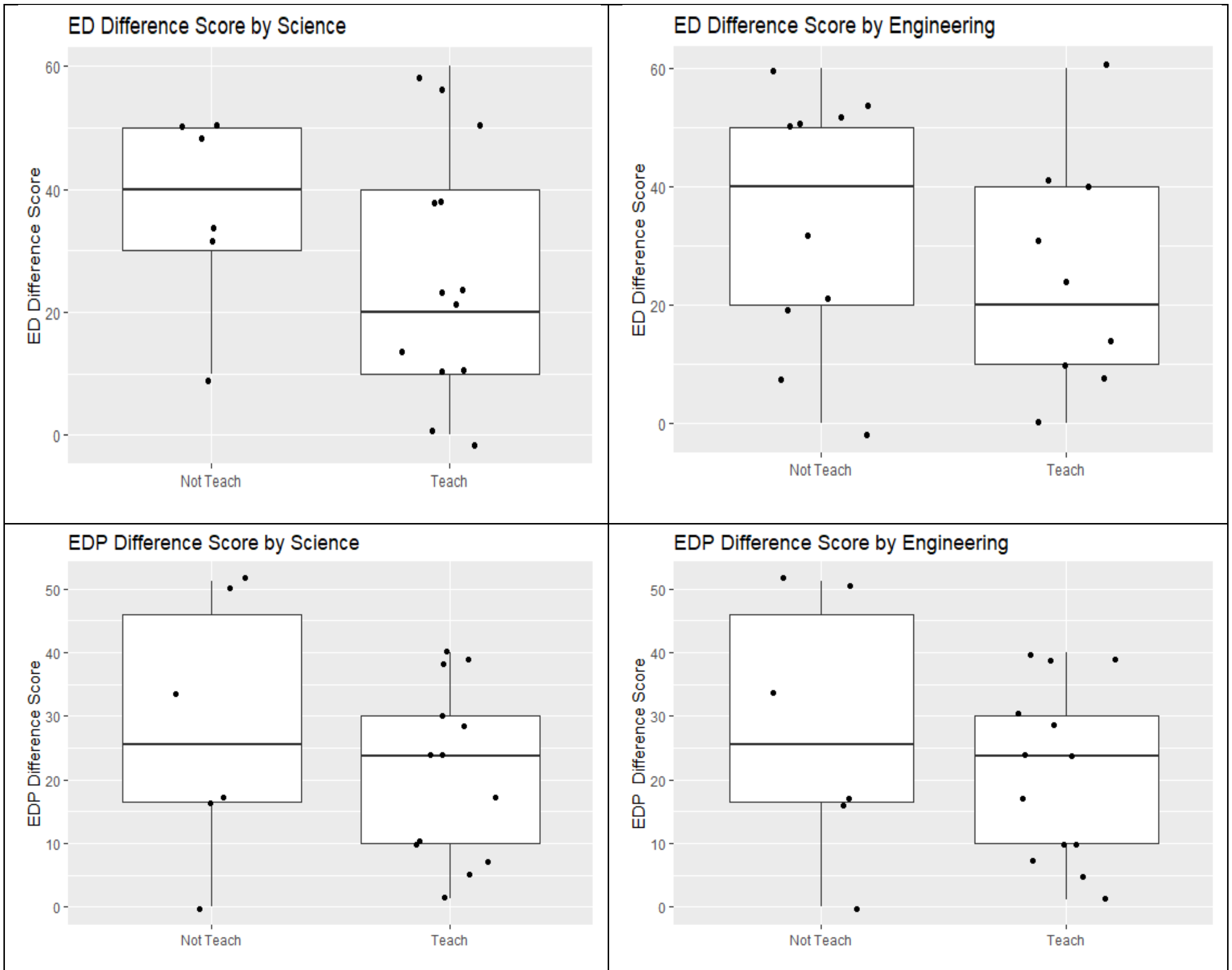

Figure 2. Box and wisker plots of difference scores (postscore – prescore) for Engineering Design Self-Efficacy Instrument (EDSI). Plots on the left are dissagregated by whether or not participants teach science. Plots on the right are disaggregated by whether or not partiicpants have previously taught engineeirng activities. ED = engineering design self-efficacy; EDP = engineering design process self-efficacy