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Ongoing Investigation of Elementary Teachers' Engineering Self-Efficacy Following Their Participation in an Online Professional Learning Program

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NSF DRK-12: Ongoing Investigation of Elementary Teachers' Engineering Self-Efficacy Following Their Participation in an Online Professional Learning Program

Introduction

Engineering education prepares students to think critically, make decisions, and pursue STEM careers and educational trajectories. The three-dimensional approach to STEM instruction and the integration of engineering within *A Framework for K-12 Science Education* represents a paradigm shift embodied by the Next Generation Science Standards (NGSS) (National Research Council, 2012; NGSS Lead States, 2013). Well-prepared teachers are necessary to enact ambitious vision in classrooms (Banilower et al., 2019). Prior research has raised concerns about the number of elementary teachers who lack the self-efficacy needed to incorporate engineering in their lessons (Hammack & Ivey, 2017; Cadero-Smith, 2020). Because self-efficacy is associated with classroom behaviors and student learning (Yoon et al., 2014), fostering teachers' self-efficacy is an important outcome for engineering-focused professional learning programs.

Conceptual Framework

Teachers' self-efficacy in science and engineering has been shown to directly affect the effectiveness of their instruction (Hammack & Ivey, 2017; Zee & Koomen, 2016). An individual's self-efficacy represents their conviction they can successfully produce desired outcomes (Bandura, 1977; 1982). One dimension of self-efficacy, termed efficacy expectation, refers to individuals closely held belief that they can successfully perform the behavior required to achieve the desired outcome. Another dimension, outcome expectancy, refers to an individual's belief that carrying out that behavior will result in the expected outcome. Researchers have investigated facets of engineering teaching self-efficacy and outcome expectancy (e.g., Yoon et al., 2014), and there is evidence that dimensions can be bolstered through professional learning and intervention.

Given that self-efficacy comes from many sources, it can be deliberately targeted as part of teacher professional learning, by providing teachers with mastery experiences (e.g., achieving an instructional goal), vicarious experiences (e.g., observing a role model succeeding while teaching engineering), physical and affective states (e.g., positive emotions associated with meaningful engineering lessons), and social support (e.g., role model or peer support, during or after instruction). Prior research has indicated that activities that involve explicit reflection and those that develop teachers' content and pedagogical mastery have the most profound positive impacts on teachers overall engineering self-efficacy (Yesilyurt et al., 2021). Further understanding the components of effective professional development that have the greatest impact on teachers' engineering education self-efficacy and outcome expectancy, including delivery and enactment, offers a promising pathway towards improving K-12 teaching and learning.

Research Questions

RQ1) To what extent did the blended asynchronous and synchronous PL activities in 2024 improve elementary teachers' self-efficacy and outcome expectations associated with NGSS-aligned engineering instruction?

RQ2) What changes, if any, were observed in teachers' engineering self-efficacy while they engaged with modest instructional supports during the 2024-2025 academic year?

RQ3) What changes, if any, were observed among the 2023 cohort of teachers who continued participating in PL activities during the 2024-2025 academic year?

Project Description

Participants

Researchers located in CA, MT, ND, and WY coordinated the recruitment of rural elementary teachers. This study had a sample of 165 teachers. Seventy-five of these teachers were returning participants who started the PL program in 2023 (Summers et al., 2025). The other 90 teachers in the sample represented the 2024 cohort, who participated in the professional learning intervention, described in the section below, and research activities between July 2024 and June 2025. The 2024 cohort participants were distributed across CA, MT, ND, and WY (17-27 teachers per state). Teachers in the 2024 cohort taught the following grades during the study period: 3 (n=25; 27.8%), 4 (n=18; 20.0%), and 5 (n=24; 26.7%), and others taught multiple grades (n=23; 25.6%).

Professional Learning Intervention

During July-August 2024 a team of PL experts facilitated an intense, online PL. The online institute was co-designed and delivered by K-12 Alliance, who have many years of experience helping educators make sense of the NGSS and delivering PL. Topics in the PL covered the shifts called for by NGSS, including 3-dimensional instruction and engineering design, along with the implications for instruction. The 2024 cohort teachers completed 2 asynchronous modules that were focused on NGSS-aligned aligned science and engineering. The engineering module also introduced teachers to engineering design in elementary classrooms (authentic video episodes showing the 2023 cohort). There were two days of synchronous PL, designed to reinforce the content of the asynchronous modules, which were designed to allow for collaboration. For more information about the PL intervention, see Hammack et al. (2024).

Modest Supports Throughout School Year

Over the 2024-2025 academic year, teachers were provided with modest supports to promote enduring PL outcomes (Sandholtz et al., 2023). Six 90-minute-long online professional learning community (PLC) sessions were delivered online, synchronously during 2024-2025. Two 90-minute-long online PLC sessions were engineering-focused, which will be briefly summarized for the purposes of this paper (see Hammack et al., 2024; Summers et al., 2025). The first of these PLC sessions, led by members of the research team, introduced participants to the Community Relevant Engineering Design (CRED) Framework (Bowman et al., 2024). Teachers used this framework to design engineering lessons around extreme weather problems specific to their place. The second of these PLC sessions provided participants with the opportunity to work collaboratively in grade-level breakout rooms to finalize their CRED lesson plans. Participants were also given access to a variety of electronic supports via a Google Classroom, materials for delivering these lessons in their classrooms, and structured opportunities to connect with peers (e.g., project website, social media).

Measures

Our research team administered the Teacher Efficacy and Attitudes toward STEM (T-STEM) Survey (Friday Institute for Educational Innovation, 2012) to the 2024 cohort before and immediately following the summer PL institute (July-August 2024). The 2023 cohort participants that stayed involved in PL activities also provided responses in August 2024. All participating teachers electronically completed the Engineering Teaching Efficacy and Beliefs (11 items) and the Engineering Teaching Outcome Expectancy (9 items) subscales of the T-STEM Survey through Qualtrics. A delayed post-PL survey was administered to all participants near the end of the school year (May 2025).

Data Analysis

Data were analyzed in R (Bryer & Speerschneider, 2016). Confirmatory factor analysis results approached satisfactory model fit across all time points. Comparative Fit Index ranged .83 to .93 (>.90; Byrne, 1994), which were acceptable, and Tucker Lewis Index ranged .79 to .94 with good fit (>.90; Bentler & Bonett, 1980). Each of the T-STEM subscales used displayed acceptable internal consistency and reliability for each time point (Taber, 2018); Cronbach's alpha self-efficacy (.74 to .86) and outcome expectancy (.89 to .91). Paired t-tests were used to investigate differences in the mean responses collected using these subscales between time points. Adjusted p-values were computed to check statistical significance of pairwise comparisons. The 2024 cohort data was also examined using repeated measures ANOVA to investigate the data collection time points simultaneously (pre-PL, immediate post-PL, and delayed post-PL). Mauchly's test of sphericity was used to examine the variances of the differences between all combinations of time points within cohorts.

Results

For the 2024 cohort, changes in participants' engineering self-efficacy between pre-PL and immediate post-PL (RQ1) indicated a significant increase in, $t(75) = -5.33$, $p = <.001$. The observed change in outcome expectancy during the same period appeared to be significant, $t(74) = -2.16$, $p = <.034$, but did not meet the significance according to the Bonferroni-adjusted p-value (0.103). The intervention had a moderate effect on participants' self-efficacy, based on the computed Cohen's d (.54) (Cohen, 1988).

Paired t-tests were used to investigate changes observed among the 2024 cohort during the academic year (RQ2). Results indicate a significant increase in participants' engineering self-efficacy between the immediate post- and the delayed post-PL time points, $t(70) = -9.69$, $p = <.001$. The change in outcome expectancy during the same period was also significant, $t(69) = -2.93$, $p = .014$ (adjusted). Investigating change across the three time points simultaneously, using repeated measures ANOVA, indicate significant changes in participants' efficacy beliefs. For the *Engineering Teaching Efficacy and Beliefs* scale, the mean scores significantly increased from 2.92 (SD = .78) pre-PL to 3.29 (SD = .59) immediate post-PL, then increased further to 3.81 (SD = .49) when captured at the delayed post-PL. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(66) = .79$, $p = <.001$. Adjusted values were significant: Greenhouse-Geisser, $F(2, 132) = .83$, $p <.001$; Huynh-Feldt, $F(2, 132) = .84$, p <.001. Participants' average responses on the *Engineering Teaching Outcome Expectancy* scale also increased significantly, $F(2, 130) = 11.19$, $p <.001$. Mean scores increased, 3.45 (SD = .51) pre-PL to 3.52 (SD = .51) immediate post-PL, and further increased to 3.68 (SD = .56) in May 2025.

Reviewing T-STEM responses collected from teachers in the 2023 cohort (RQ3), between the start of fall 2024 and the end of spring 2025, revealed a significant increase in teachers' engineering self-efficacy, $t(66) = -8.36$, $p = <.001$. Ongoing participation in the PL intervention had a moderate effect on participants' engineering teaching self-efficacy (n=73), shown by an increase in participants average responses to scale items from 3.53 (SD = .43) to 3.92 (SD = .54). Based on the computed Cohen's d (.80), this was a moderate-large effect. Changes in outcome expectancy were marginal, teachers' average responses increased 3.62 (.44) to 3.73 (.62), but, ultimately, were not significant changes, $t(66) = -1.82$, $p = .074$.

Discussion

The 2024 cohort participants showed growth in their engineering self-efficacy pre- and immediate post-PL following intense, online PL. For this cohort of teachers, their self-efficacy became increasingly positive over the 2024-2025 academic year, along with their outcome expectancy. This is notable because teachers' responses collected in prior years, which were reported previously (see Summers et al., 2025), indicated that outcome expectancy changed significantly across the intense online PL and the activities during the following school year. Overall, the 2024-2025 findings are consistent with prior research that have leveraged similar interventions with elementary teachers (Sandholtz et al., 2023). Teachers were provided with modest instructional supports, which included PLC sessions directed at helping them to deliver NGSS-aligned and place-centered engineering lessons. It is important to note that only a portion of the long-term intervention was engineering-focused, 2 of 6 PLC sessions along with some specific electronic supports. These findings seem to coincide with prior research that have reported teachers benefit from structured collaboration and support over time (Weddle, 2022). This is reinforced by the 2023 cohort data presented, longer-term participant monitoring, which continues to show significant positive changes during their second year in the PL program. Collectively, results from this study have implications for improving teacher PL design and delivery as well as improving student learning through classroom instruction.

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