Abstract

Despite the intent to advance engineering education with NGSS, teachers across all grades lack self-efficacy in engineering pedagogy. Instructional shifts envisioned by NGSS, especially with inclusion of engineering, require substantial learning by teachers. For rural schools, due to geographic location and smaller collegial networks, there are challenges in providing content-specific professional learning. This project gathered researchers from four states to provide PL aligned to NGSS and delivered remotely to 150 rural teachers. In summer 2023, experts led a five-day workshop which modeled shifts called for by NGSS (e.g., equitable, discourse-rich, phenomena-based) and provided opportunities to experience next-generation teaching and learning. Likert scale surveys were collected before and after the workshop to gauge self-efficacy regarding teaching science and engineering. We found that science-focused PL, with engineering embedded rather than as stand-alone component, afforded growth in self-efficacy for teaching engineering. Pre-workshop surveys showed that teachers had higher self-efficacy towards teaching science than teaching engineering (Wilcoxon signed-rank; $p<.001$). Positive attitudes toward teaching science were leveraged to provide PL and pre-workshop to post-workshop analysis showed growth in self-efficacy towards teaching engineering ($p<.001$). Results are important for professional learning around teaching engineering, for professional learning with rural teachers, and for remote access to professional learning.

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Science Professional Learning that Offers Opportunities for Growth in Engineering Self-Efficacy for Rural School Elementary Teachers

Subject

Implementing NGSS, especially with its vision for three-dimensional science learning, requires substantial shifts in science teaching (Moon et al., 2012; Windschitl & Stroupe, 2017). Correspondingly, these shifts require substantial learning by teachers, administrators, and others within the education system. Since the release of the standards, many questions have surfaced about their implementation and about supports for and barriers to their implementation (e.g., Brunsell et al., 2014).

For the first time, with the adoption of NGSS, K–12 students are expected to learn engineering alongside science. As noted in Appendix D of the NGSS, the application of engineering in these standards "has the potential to be inclusive of students who have been traditionally marginalized in the science classroom" (NGSS Lead States, 2013, p. 29). These rigorous and forward-thinking standards offer opportunities to close achievement gaps (Breton, 2017). However, despite the intent to advance engineering education with the NGSS, teachers across all grade levels lack confidence in their engineering content knowledge and pedagogy and report low levels of engineering self-efficacy (Authors, 2019). To date, there has been insufficient professional learning aligned to NGSS that includes engineering and that also reflects the features associated with best practices (Darling-Hammond et al., 2017). We need to ensure that teachers are prepared to teach high-quality engineering alongside NGSS-aligned science, so that students can benefit from these opportunities.

Preparing teachers is one of the most important factors in supporting student success (Darling-Hammond, 2000). Considering the ambitious vision of learning established in the *Framework* (NRC, 2012), and the inclusion of engineering design in the NGSS, high-quality professional learning is essential in order to shift teachers' instructional practices (Authors, 2020; Britton et al., 2020). Teacher participation in effective professional learning offers a promising approach to improving science instruction. Elementary teachers feel less prepared to teach science than mathematics and language arts (Banilower et al., 2018; Dorph et al., 2011; Weiss et al., 2001), and engineering even less so (Banilower et al., 2018). Without teachers who are prepared and confident in their ability to teach engineering, elementary students are unlikely to encounter high-quality science and/or engineering instruction (Dorph et al., 2011).

Due to geographic location and smaller networks of colleagues who teach science, rural schools encounter acute challenges in recruiting and retaining teachers (Arnold et al., 2005) and providing content-specific professional learning (Harmon & Smith, 2007). While some initiatives have reported growth in teachers' pedagogical preparedness, science content preparedness, and use of reform-oriented teaching practices (e.g., Harmon & Smith, 2007; Heck et al., 2004), more work is needed. This project brought together researchers from four states with large rural districts to provide professional learning aligned to NGSS and delivered remotely. Through analysis of survey data before and after a week-long workshop, we sought to answer two research questions: 1) To what extent did the intensive professional learning experience enhance teachers' knowledge of NGSS-aligned teaching strategies related to science and engineering? 2) To what extent did the intensive professional learning experience improve teachers' confidence toward engineering teaching and learning?

Method

Context for Professional Learning

In the summer of 2023, a team of professional learning experts led a five-day PL. The PL team was composed of a lead science PL expert associated with a professional learning organization, one expert in engineering PL, one expert in PL for rural school teachers, and several researchers with backgrounds in science and engineering teacher PL. The PL was designed to be curriculum-agnostic and fully online.

PL modeled instructional shifts called for by the NGSS (e.g., equitable, discourse-rich, and phenomena-based) and provided teachers with opportunities to experience the benefits of next-generation teaching and learning for themselves. Teachers were engaged in adult-level, hands-on investigations as a way to deepen their understanding of three-dimensional learning. The PL also provided materials via mail, so that teachers could use the materials to engage in hands-on engineering learning in their own spaces while participating in PL activities online.

Topics covered in the PL included the shifts called for by NGSS and the implications for instruction; the three dimensions that support students' sensemaking of phenomena and solving of problems; and authentic, relevant, and meaningful science and engineering instruction that supports all student,; among others.

Participants

Coordinators from the four rural states enrolled a minimum of 35 teachers each for a total of 150 teachers. There was a range of experience across the group but more than half (55%) had been teaching for more than 10 years. Participants were equally represented from grades 3 (36%), 4 (32%) and 5 (32%). All participants had experience teaching in rural schools prior to participating in the PL.

Data Collection and Analysis

Three surveys were collected from the participants: 1) a needs assessment survey, which asked questions regarding instructional materials, classroom resources, and technology; 2) a pre-workshop survey, which asked questions regarding teacher objectives, feelings about teaching and learning of both science and engineering, days and time spent teaching a variety of subjects, teacher leadership, and STEM career awareness; and 3) a post-workshop survey, which asked questions regarding feelings about teaching and learning of both science and engineering, and the topics that were covered during the workshop. All 150 teachers completed the pre-workshop survey while 111 completed the post-workshop survey. (As the workshop just concluded at the end of the first week in August, we are actively soliciting additional post-workshop surveys.)

Our focus for this proposal was on two categories of questions from the pre-workshop survey, "Feelings About Teaching Science" and "Feelings About Teaching Engineering," plus one category, "Feelings About Teaching Engineering," from both the pre-workshop survey and the post-workshop survey. Table 1 shows the items from the "Teaching Science" category while the "Teaching Engineering" questions used an identical structure. The items in these categories were scored on a five-point Likert scale ranging from strongly disagree to strongly agree.

Data were analyzed both descriptively, using the Likert package in R (Bryer & Speerschneider, 2016), and statistically, using a Wilcoxon signed-rank test. For the Wilcoxon test, data were reduced from five levels to three levels, combining strongly disagree with disagree and combining agree with strongly agree. The pre-workshop analysis of teachers' feelings about teaching science compared to their feelings about teaching engineering drew from surveys provided by all 150 teachers. The pre-/post- comparison of teachers' feelings about teaching engineering used only data from the 111 teachers who submitted post-workshop surveys. For both sets of analyses, the Wilcoxon tests were applied to each question separately and looked at individual differences in each teachers' rankings on those questions.

Table 1

Questions Regarding Teachers' Feelings About Teaching Science

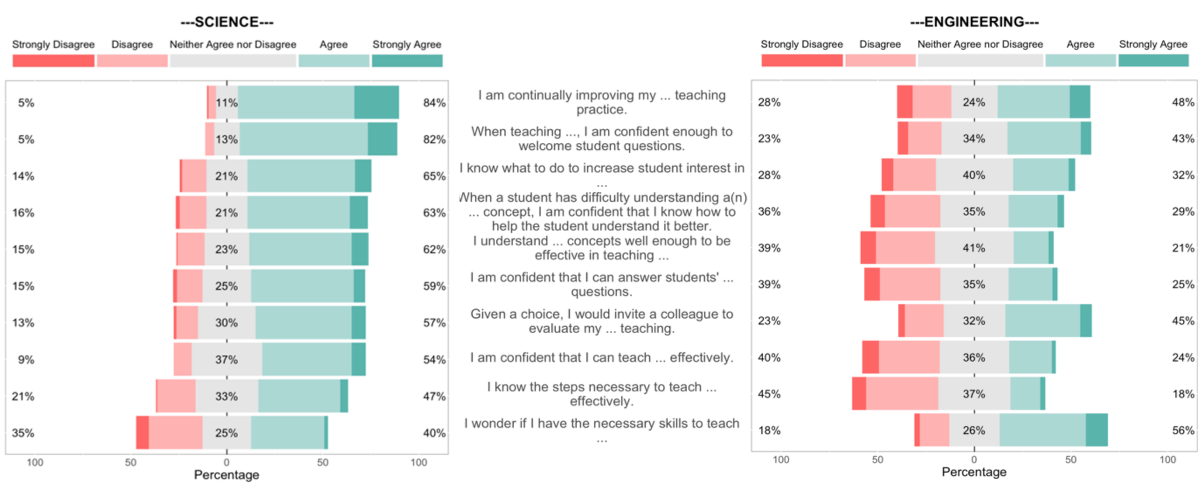
1. I am continually improving my science teaching practice.
2. I know the steps necessary to teach engineering effectively.
3. I am confident that I can teach engineering effectively.
4. I wonder if I have the necessary skills to teach engineering.
5. I understand engineering concepts well enough to be effective in teaching engineering.
6. Given a choice, I would invite a colleague to evaluate my engineering teaching.
7. I am confident that I can answer students' engineering questions.
8. When a student has difficulty understanding an engineering concept, I am confident that I know how to help the student understand it better.
9. When teaching engineering, I am confident enough to welcome student questions.
10. I know what to do to increase student interest in engineering.

Findings

To answer the first research question (the extent to which professional learning enhanced teachers' knowledge of teaching strategies related to science and engineering) we began with a comparison of teachers' self-efficacy regarding teaching science to their self-efficacy about teaching engineering *before* the summer workshop. In short, this group of teachers demonstrated much more confidence in teaching science than they did in teaching engineering. Figure 1 shows how the teachers responded to each question for science (on the left) and for engineering (on the right). Ranked by the largest percentage agreement to the questions for science, we observed higher levels of self-efficacy for teaching science based on all ten questions. The only question with higher agreement for engineering was the question about the skills necessary to teach science and engineering. Since this question was phrased in the negative ("I wonder if..."), implying doubt or confusion, the more confident teachers disagreed and the less confident teachers agreed.

Figure 1

Teachers' Feelings About Their Own Teaching of Science and Engineering Before the Workshop

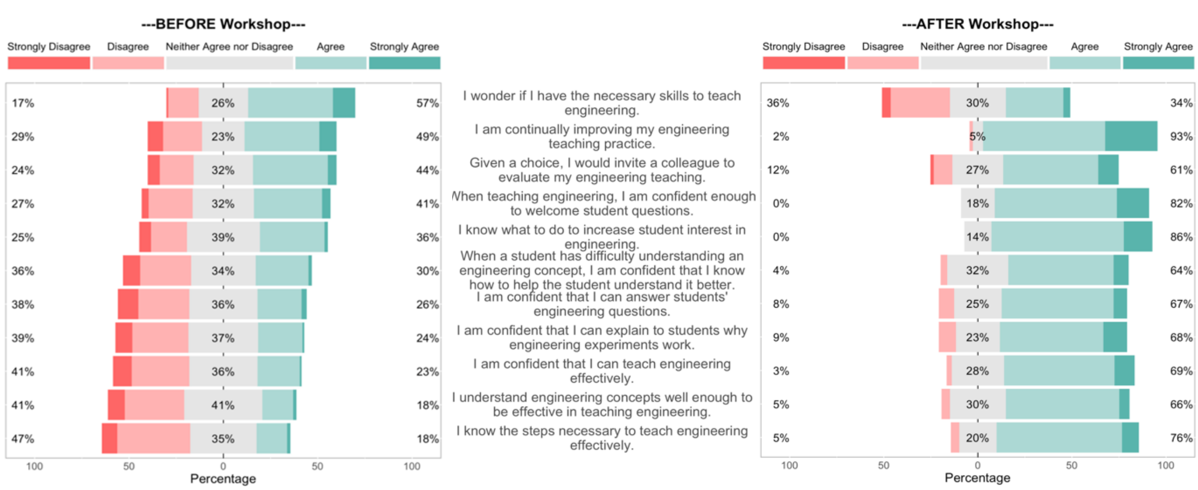


There were significant differences ($p<.001$) across all ten questions. The smallest difference (V=66) was the question about inviting a colleague to observe their teaching. Teachers were more likely to invite a colleague to observe their science teaching than to observe their engineering teaching. While 57% agreed (or strongly agreed) for science and only 13% disagreed, only 47% agreed for engineering and 23% disagreed. The largest difference (V=1902) was the question about the skills necessary to teach science and engineering. For science, 35% disagreed that they might have the necessary skills and 40% agreed, while for engineering only 18% disagreed and 56% agreed. Also notable was the large percentage of teachers (45%) who disagreed on knowing the steps to teach engineering (V=424) compared to only 18% who agreed. Responses to this question for science were reversed with 47% agreeing that they knew the steps to teach science while only 21% disagreed.

To complete our analysis of the first research question, and to answer the second research question regarding how professional learning affected teachers' attitudes and self-efficacy toward engineering teaching and learning, we compared their responses on 11 questions (see Figure 2) before the workshop (on the left) and after the workshop (on the right). (These were the same ten questions used in the earlier analysis with the addition of one question about confidence related to explaining engineering experiments.) The questions are ranked according to percentage agreement before the workshop.

Figure 2

Teachers' Feelings About Their Own Teaching of Engineering Before and After the Workshop



The professional learning that was provided in the workshop was focused mostly on science, yet teachers were able to access engineering concepts and develop pedagogical skills that gave them confidence in teaching engineering. We found growth in positive self-efficacy for teaching engineering ranging from 17% (inviting a colleague to evaluate engineering teaching [V=1121]) to 58% (knowing the steps to teach engineering [V=3252]). This indicated that teachers felt more confident after the PL that they could think methodically about teaching engineering to their students. The question regarding skills to teach engineering (V=393), phrased again in the negative, saw a decrease in agreement of 23% and an increase in disagreement of 19%. On two questions, confidence in welcoming student questions and knowing how to increase student interest, the level of disagreement in the post-survey was 0%. All eleven questions showed significant change (p<.001) from before the workshop to after the workshop.

Further evidence from the pre-/post- comparisons reinforced the idea that professional learning focused on science instruction, with engineering appropriately embedded and not as a stand-alone, affords growth in self-efficacy for teaching engineering. Before the workshop, in a series of questions about students' learning of engineering (unreported here due to space limitations), only 21% of teachers agreed that student's learning of engineering is directly related to their teacher's effectiveness at teaching engineering, while 39% disagreed. After the workshop, 66% agreed with this statement and only 5% disagreed. Similarly, in a post-workshop evaluation regarding the ideas that were covered, 93% of participants agreed that "Authentic, relevant, and meaningful science instruction supports all students" and 91% said the same for engineering. Though these questions about student learning were untestable for teachers during the summer break, the direct relationship between student learning and teacher effectiveness is an important gauge of teacher efficacy.

Discussion

The professional learning provided by this workshop focused on teaching and learning related to NGSS. Major topics included the shifts called for by NGSS and the implications for instruction; the three dimensions that support students' sensemaking of phenomena and solving of problems; and authentic, relevant, and meaningful science and engineering instruction that supports all students. In post-workshop evaluation, 90% of participants stated that these topics were covered "to a large extent" or "to a great extent." As such, the focus of the workshop was on science while engineering was embedded as: 1) an application of science understanding, and 2) an access point for further scientific sensemaking.

Together, the two sets of analyses show that professional learning around science (i.e., high-quality professional learning focused on the instructional shifts demanded by NGSS) affords opportunities for growth in self-efficacy around engineering. Before the workshop, teachers' attitudes and self-efficacy toward teaching science were significantly more positive than their attitudes and self-efficacy toward teaching engineering. These positive attitudes were therefore able to be leveraged as a backdoor to professional learning and growth in self-efficacy around teaching engineering. Based on teachers' pre-workshop attitudes toward teaching engineering, it is possible it may have been harder to recruit teachers into a workshop dedicated to engineering professional learning. Purposefully integrating engineering and science helped teachers feel they understood the concepts and the pedagogy more deeply and how to implement it more effectively.

Further, though the instructors for this workshop were experts in science PL, engineering PL, and rural schools, it was ambitious to conduct the workshop fully online. Yet, these results show significant growth in confidence and self-efficacy regarding teaching engineering. Given that there was no cost associated with travel or facilities, this PL model exemplifies a low-cost effort with significant gains for teacher confidence/self-efficacy to teach engineering.

Significance

The results shown here are important not only for professional learning and growth in self-efficacy around teaching engineering but also for professional learning with rural elementary teachers and remote access to professional learning. This work reaffirms the need for engineering PL support for teachers; a fully online, five-day PL saw significant changes in teachers' self-efficacy for teaching engineering. We argue that these findings provide insight on the power of NGSS-aligned PL to support teachers' confidence to teach engineering. The authors expect this poster to be of interest to NARST members researching teacher PL, NGSS implementation, and elementary science. This project highlights the potential for impactful outcomes of remote professional learning for elementary teachers' confidence and self-efficacy related to engineering.

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