

Inservice Elementary Teachers' Science and Engineering Teaching Self-Efficacy: A Synthesis of the Literature

Over the last decade in the United States, education reforms have called for a fundamental shift in K-12 science teaching and learning in order to prepare future generations to solve real-world problems using interdisciplinary knowledge and skills, including engineering (NGSS Lead States, 2013; NAE & NRC, 2014). The new vision requires those training current and future elementary teachers to overhaul courses to equip them to understand and implement NGSS standard-based learning in classrooms (French & Burrows, 2018; Reimers et al., 2015; Tuttle et al., 2016). It is long established that teachers with high self-efficacy are more likely to incorporate inquiry-based practices in their teaching and to foster learner-centered environments in their classrooms (Lakshmanan et al., 2011; Watters & Ginns, 2000). However, elementary school teachers often have low self-efficacy in science and engineering teaching and leave their teacher preparation programs feeling unprepared to teach these disciplines (Banilower et al., 2018; Custer & Daugherty, 2009; Reimers et al., 2015).

Given that self-efficacy beliefs are the strongest predictors of motivation and performance, their influence on elementary teachers' ability to teach science effectively is widely studied (Knaggs & Sondergeld, 2015; McDonald et al., 2019; Pajares & Schunk, 2001). Current findings suggest that teacher preparation programs and inservice teacher (IST) professional development (PD) enhance science teaching self-efficacy (e.g., Author, 2020; Authors, 2018; Sinclair et al., 2011). However, there is less evidence surrounding engineering teaching self-efficacy. As part of our larger NSF-funded research project, we conducted a systematic review of literature that explored the research question: What does the existing literature on self-efficacy reveal about fostering elementary teachers' science and engineering teaching self-efficacy? In this presentation, we will focus on the IST research literature.

Theoretical Framework

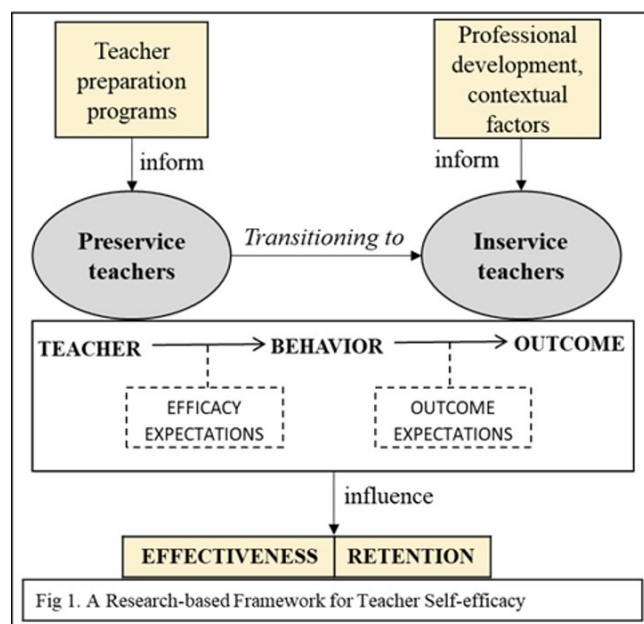
Long an influential construct in teacher education, self-efficacy was conceptualized by Bandura (1981) as a judgment about one's ability to "organize and execute courses of action" (p. 587) to achieve the desired goal. Consistent with Bandura, Tschannen-Moran et al. (1998) defined teacher efficacy as the beliefs that shape teachers' ability to execute certain actions in given desired situations, which can bring desired results. Here, teacher efficacy is context-specific, situational, and subject-matter specific, as with elementary teachers who may prefer other subjects to science because they perceive their engineering teaching as inadequate.

Self-efficacy is comprised of two dimensions: personal efficacy and outcome expectancy (Bandura, 1977). Researchers have posited that the dimensions are related but can act independently. Within teaching, personal efficacy involves teachers' beliefs in their ability to motivate and support student learning by creating rich-learning environments (Bandura, 1993); outcome expectancy links to beliefs in whether teacher actions will yield desired student outcomes. Bandura (1997) proposed four major sources of self-efficacy beliefs: mastery experiences, vicarious experiences, verbal persuasion, and emotional arousal (Bandura, 1995; 1997). These sources of self-efficacy beliefs influence an individual's expectations related to performing a specific action.

Grounded in the self-efficacy literature, we developed a framework (see Figure 1) that allows for an in-depth understanding of experiences critical to the development of teaching self-efficacy. The framework guided our systematic literature review in order to identify gaps and

recommendations for future research in science and engineering teaching self-efficacy. The model recognizes the dynamic nature of self-efficacy, which can change with experiences gained within various formal and informal professional contexts. We posit that the experiences teachers have in preparation programs and PD contexts influence their behaviors and outcome expectancies, which thereby influence their teaching effectiveness and retention in the field.

Figure 1
Teaching Self-Efficacy Model

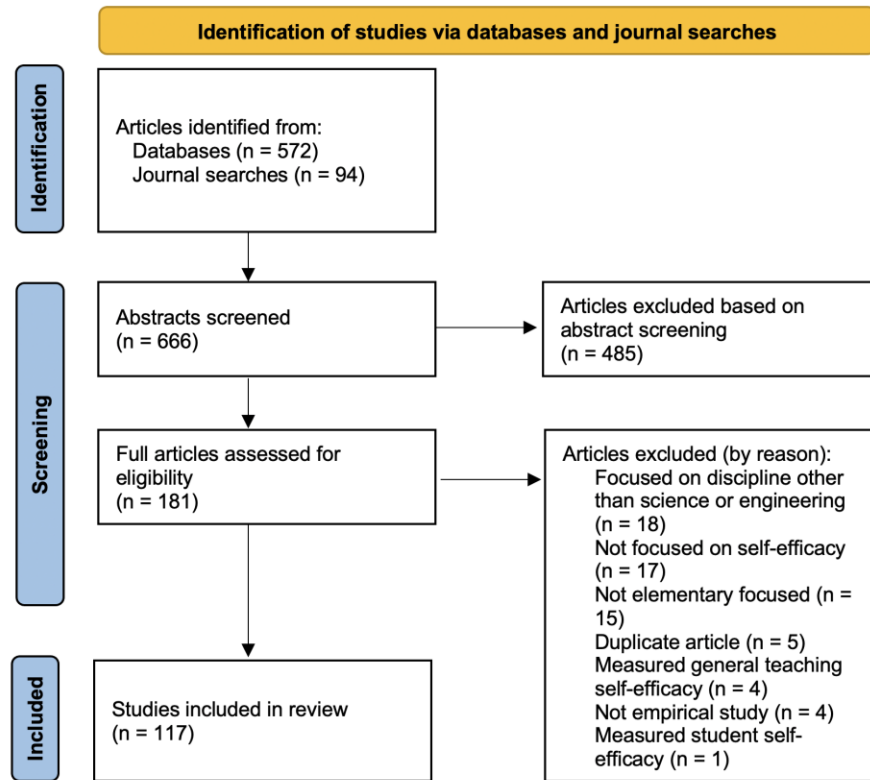


Research Design: Systematic Literature Review

We conducted a systematic literature review based on Newman and Gough's (2020) recommendations to answer our overarching research question: What does the existing literature on science and engineering teaching self-efficacy reveal about fostering elementary teachers' science and engineering teaching self-efficacy? First, we defined our inclusion criteria for article selection: (1) published between 2010 and 2022, (2) empirical studies only, (3) focus on elementary (K-6) teachers (preservice and inservice), (4) focus on self-efficacy for teaching science and/or engineering, (5) peer-reviewed, and (6) published in English.

Second, we conducted several database searches, testing various combinations of search terms to yield the most relevant results. In reviewing the 572 results from the database search, we identified several prominent journals that were not represented in the findings. We conducted a second round of individual searches within these journals, resulting in an additional 94 articles. With the 666 resulting publications, we conducted several rounds of review, coding, and analysis of the studies, resulting in a total of 117 articles included in our full systematic review (see Figure 2).

Figure 2
Systematic Review Flow Diagram



Findings

Among the 117 articles included in our full systematic review of science and engineering teaching self-efficacy, only 22 empirical studies focused on approaches to supporting science and engineering teaching self-efficacy among ISTs. In this section, we will describe our synthesis of these 22 studies. Eighteen of the studies focused on science teaching self-efficacy, while four focused on engineering teaching self-efficacy. Eleven studies utilized mixed methods, eight were quantitative, and three were qualitative. Sixteen studies were conducted in the U.S., and the remaining studies were conducted in Australia (n=2), China (n=1), Greece (n=1), and the Netherlands (n=2).

Science Teaching Self-Efficacy Findings

The 18 studies of science teaching self-efficacy among elementary ISTs explored a range of PD contexts, including professional learning communities (Mintzes et al., 2013), collaborative teacher curriculum design (Velthuis et al., 2015), informal science education organizations (McKinnon & Lamberts, 2014), a massive open online course (Tzovla et al., 2021), videocase-based PD (Sang et al., 2012), research experiences for teachers (Enderle et al., 2014), and online graduate coursework (Gosselin et al., 2010). Despite the range of experiences, all studies provided evidence of improved self-efficacy as a result of participation in PD, likely because these experiences were specifically designed to promote growth.

These science teaching self-efficacy studies also ranged in the number of teacher contact hours and duration. Some were relatively short in duration, with PD experiences lasting as little as four hours (McKinnon & Lamberts, 2014) or occurring across five or six weeks (e.g., Enderle et al., 2014; Tzovla et al., 2021), while others spanned multiple years (e.g., Kang et al., 2019;

Lumpe et al., 2012; Mentzer et al., 2017; Mintzes et al., 2013; Sandholtz & Ringstaff, 2014; Sandholtz et al., 2019). Notably, even those studies that utilized relatively short-term PD interventions demonstrated some positive effects on science teaching self-efficacy. For example, Tzovla et al. (2021) found that teacher participation in an online course focused on teaching biological concepts demonstrated medium to high effect sizes for self-efficacy improvements compared to teachers who did not participate.

The studies provide mixed evidence about whether PD experiences result in improvements in personal efficacy and outcome expectancy. Some studies (e.g., Gosselin et al., 2010; Mintzes et al., 2013; Sandholtz & Ringstaff, 2014; Sinclair et al., 2011; Tzovla et al., 2021) found both to be positively impacted by PD. Other studies (e.g., Enderle et al., 2014; McKinnon & Lamberts, 2014; Sang et al., 2012) reported positive effects of professional development on personal science teaching efficacy only, suggesting that science teaching outcome expectancy may be more difficult to influence through professional development. Mentzer et al. (2017) found that teachers already had high levels of outcome expectancy, so they attributed a lack of change in this area to ceiling effects.

Few studies considered the nature of the PD experiences and the specific elements that contributed to improved teacher self-efficacy. One notable exception is Palmer (2011), who specifically studied the sources of self-efficacy beliefs among teachers who experienced a PD intervention intentionally designed to provide them with a range of experiences. In this study, increases in self-efficacy were primarily the result of cognitive mastery, or perceived success in understanding how to teach science, and feedback on instructional practices (verbal persuasion); vicarious experiences and enactive mastery were less central in influencing self-efficacy beliefs. Mintzes et al. (2013) also considered various sources of self-efficacy beliefs, identifying that mastery and vicarious experiences, as well as emotional reinforcement and social persuasion, all contributed to shifts in teaching self-efficacy.

While self-efficacy is a useful goal in itself, it is important to consider whether teachers with higher teaching self-efficacy also demonstrate higher quality instruction. Indeed, some studies have found this to be true, with growth in self-efficacy translating into classroom practice in terms of the amount of instructional time or quality of instructional practices (e.g., Kang et al., 2019; Sandholtz & Ringstaff, 2011; Sandholtz & Ringstaff, 2014). However, van Aalderen-Smeets & van der Molen (2015) note that despite improvements, only $\frac{1}{4}$ of teacher participants reported teaching science at least once a month, showing much room for improvement remains even after PD experiences. Mentzer et al. (2017) found that changes in instruction took two or three years to observe. Further, not all studies showed that improved self-efficacy was linked to changes in instruction. Despite growth in science teaching self-efficacy, elementary teacher participants in Enderle et al.'s (2014) research experiences for teachers did not demonstrate improved instructional practices. Granger et al. (2019) found that teachers who entered their PD experience with high levels of self-efficacy experienced less learning; interestingly, this was also true of their students, who learned less than students of teachers who entered with lower self-efficacy levels. In another study that explored connections between PD, self-efficacy, and student outcomes, Lumpe et al. (2012) found that student science achievement was predicted by the number of hours their teachers participated in the PD program. However, many other factors, including resources, instructional time and testing requirements in mathematics and language arts, classroom practices, and administrative and peer support also likely influence the links between teacher self-efficacy and student outcomes (e.g., Lumpe et al., 2012; Sandholtz et al., 2019; Sandholtz & Ringstaff, 2011; Sandholtz & Ringstaff, 2014).

Engineering Teaching Self-Efficacy Findings

The four engineering self-efficacy studies considered whether particular PD approaches supported improved engineering teaching self-efficacy among participants. The total number of participants ranged from 14-43 in these studies. Three of the studies (Ficklin et al., 2020; Parker et al., 2020; Utley et al., 2019) focused specifically on PD related to the Engineering is Elementary (EiE®) curriculum, and the fourth study (Rich et al., 2017) also included experiences that utilized EiE® materials. These PD experiences ranged from a single day of training (Ficklin et al., 2020) to a full year of weekly PD sessions (Rich et al., 2017). Findings revealed positive effects of the PD experiences on elementary teachers' engineering teaching self-efficacy (Ficklin et al., 2020; Parker et al., 2020; Rich et al., 2017; Utley et al., 2019). While long-term PD is known to be beneficial to teachers (e.g., Desimone, 2009), these findings suggest that even short-term engineering PD experiences can be beneficial to elementary teachers.

Gaps in the Literature and Future Directions

While the aforementioned studies provide promising results related to the effects of PD on ISTs' science and engineering teaching self-efficacy, it is important to note that significant gaps in the literature remain. Findings related to personal teaching efficacy and outcome expectancy are inconsistent, and it is unclear why some PD experiences support improved outcome expectancy, while others do not. With a range of different PD contexts, durations, and foci, it is difficult to disentangle the effects of the many factors that may relate to self-efficacy. Further, at times, the specific contexts in which these PD experiences occur are insufficiently detailed, leaving questions about the possibility of replication. Concerns about generalizability are further magnified within engineering contexts, with only four studies on IST self-efficacy.

Longitudinal studies are greatly needed to better understand shifts in self-efficacy over time and whether positive effects of PD experiences persist over time. The sustainability of these outcomes must be considered (Sandholtz et al., 2019), particularly as teachers face new challenges and constraints in their teaching contexts.

Further, it is unclear to what extent and in which contexts positive shifts in self-efficacy translate to improved teaching practices. Qualitative research that elaborates on a context to understand how or why changes occur (Hatch, 2002) is much needed. Qualitative and mixed-methods studies that attend carefully to the specific aspects of PD experiences that advance science and engineering teaching self-efficacy are needed to inform the design of quality PD experiences.

Contribution to Science Teaching and Learning and Impact on NARST Members

As we reviewed the body of research on science and engineering teaching self-efficacy, we synthesized the insights found therein while simultaneously recognizing persistent gaps in the literature. We acknowledge the dynamic nature of teaching self-efficacy and recognize the need for a deeper examination of the nature, characteristics, and specific aspects of contexts that support the development of engineering teaching self-efficacy among elementary teachers. Our hope is for our future empirical studies to generate a set of research-based recommendations for teacher education and PD opportunities that support science and engineering teaching self-efficacy development, and thereby influence teaching effectiveness and teacher retention. This presentation will be of interest to NARST members involved in teacher professional learning related to science and engineering education. In particular, those with an interest in elementary teaching will find this presentation useful.

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