Science and Engineering Teaching Self-Efficacy: A Systematic Literature Review

Abstract

Self-efficacy is a topic of great interest in elementary preservice and inservice teacher education, considering that elementary teachers often have low science and engineering teaching self-efficacy. In this systematic review, we synthesize existing research to reveal trends and uncover existing gaps, including recommendations for future research. Out of 117, we found 84 articles studied preservice, 31 inservice and two articles studied both preservice/inservice teachers' self-efficacy. Findings from thematic analysis indicate that the diversity of teacher education programs, both across the United States and globally, offers a rich context for considering a range of programmatic features that impact elementary teachers' science and engineering teaching self-efficacy. Implications for future research and practice in multiple contexts across teacher preparation programs are discussed.

Over the last decade in the United States, education reforms have called for a fundamental shift in K-12 science teaching and learning 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 science 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 teaching science and engineering and leave their preservice teacher (PST) preparation programs feeling unprepared to teach these subjects (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 the ability of elementary teachers to teach science effectively is widely studied (Knaggs & Sondergeld, 2015; McDonald et al., 2019; Pajares & Schunk, 2001). 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?

Theoretical Framework

Self-efficacy derives from Social Cognitive Theory (Bandura, 1986; Nespor, 1987; Pajaras, 1992), which blends behaviorist and cognitive theories. Bandura (1981) conceptualized self-efficacy as a judgment about one's ability to "organize and execute courses of action" (p. 587) to achieve the desired goal. Teacher efficacy is context-specific, situational, and subject-matter specific, as with elementary teachers who may prefer other subjects to science or engineering because they perceive their teaching as inadequate. Self-efficacy consists of two dimensions: personal science teaching efficacy (PSTE) and outcome expectancy (STOE) (Bandura, 1977). Personal efficacy involves teachers' beliefs in their abilities to motivate and support student learning by creating rich learning environments (Bandura, 1993); outcome expectancy links to beliefs about whether their 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 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 self-efficacy within the PST preparation years, during the first years of teaching, and beyond the beginning years of teaching. The framework guided our systematic literature review in order to identify gaps and recommendations for future research in science and engineering teaching self-efficacy.

Methodology

We conducted a systematic review based on Newman and Gough's (2020) recommendations to answer our research questions. First, we defined our inclusion criteria for article selection:

- Published between 2010 and 2022
- Empirical studies only
- Focus on elementary (K-6) teachers (preservice and inservice)
- Focus on self-efficacy for teaching science and/or engineering
- Peer-reviewed
- Published in English.

Second, we conducted searches in databases, including EBSCO Education Source, APA PsychInfo, and Education Resources Information Center. Several combinations of search terms were tested; the terms that yielded the most relevant results are shown in Table 1. We also used the search functions to align with the screening criteria - to limit publication dates to 2010-present and restrict search results to peer-reviewed publications.

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 (*School Science and Mathematics*, *Journal of Science Teacher Education*, and *International Journal of Science and Mathematics Education*), resulting in an additional 94 articles. With the 666 publications, we conducted several rounds of review, coding, and analysis of the studies (see Figure 2). We initially screened the titles and abstracts, 485 articles were excluded at this stage. The full texts of the remaining 181 articles were downloaded and reviewed in detail to examine several criteria: focus (science or engineering), methodology, participant type (preservice or inservice), number of participants, country in which the study was conducted, research context, data sources (instruments used and/or qualitative sources of data), results, and conclusions.

To avoid researcher bias, the second researcher cross-checked the analysis conducted by the first researcher. An additional 66 were excluded because they did not align with our inclusion criteria resulting in a total of 117 articles. The articles retained were analyzed using thematic analysis (Nowell et al., 2017). Four researchers randomly selected and independently coded ten articles to identify emerging codes and themes from the data. After the discussion and reaching consensus, ten additional articles were coded. Then, a coding scheme was developed to understand the trends in the literature, the significance of the findings, gaps, and future directions highlighted in the articles.

Findings

When examining the years in which the 117 articles were published, we found that the number of articles varied between seven to 13 articles in one year, with an exception of no article published in 2011 (see Figure 3). 71 studies were conducted in the USA, 22 were conducted in Turkey, and the remaining 24 studies took place in 14 different countries. As for the methodology, 47% (N=55) employed mixed methods, 43% used qualitative methods (N=50), and 10% (N=12) used quantitative methods to analyze the data related to science or engineering teaching self-efficacy. Out of 117 articles, 84 empirical studies focused on PSTs, 31 studies focused on inservice teachers, and two studies explored both preservice and inservice teachers. In this proposal, we discuss the themes found in the studies that focused on PSTs' science and engineering teaching self-efficacy. A closer look at the context and intervention revealed that out of 84 articles on PST, 76 (90%) studies investigated science, and only eight (10%) focused on engineering teaching self-efficacy.

Preservice Science Teaching Self-Efficacy: Trends

Out of 84 studies of PST science teaching self-efficacy, 46 were conducted in science methods courses, with two different designs that were prominent: science methods course with no practicum (n=32), and science methods course with an embedded field-based component (n=14). Many studies reported increases in self-efficacy based on qualitative methods only; however, the Science Teaching Efficacy Belief Instrument (STEBI) Form B (Enochs & Riggs, 1990) was the most popular survey employed within studies that used quantitative or mixed methods. Out of 84 studies, 18 were large-scale studies that reported descriptive statistics from a PST survey with insufficient details about the elementary teacher preparation programs.

In general, most of the science methods courses supported the development of PSTs' self-efficacy in a variety of ways in that they engaged learners in inquiry-based activities (Seung et al., 2019; Soprano & Yang, 2013) that modeled reform-based pedagogies such as 5E model (Bybee, 1997; Bergman & Novacek, 2021), science and engineering practices (Kang et al., 2019), and argument-driven inquiry (Aydeniz & Ozdilek, 2016; Eymur & Çetin, 2017). Lesson design, implementation of the lesson in an elementary classroom, and reflections on teaching were important elements for courses with an embedded practicum experience (Authors, 2020; 2021; Aydeniz & Ozdilek, 2016; Bergman & Novacek, 2021; Eckhoff, 2017; Leonard et al., 2011; McDonnough & Matkins, 2010; Rinke et al., 2016). Evidence highlights the significance of field experiences and student teaching in instilling self-efficacy for science teaching, but whether field teaching should be part of the science methods course or follow immediately after remains a subject of debate. Studies reporting the impact of field experiences have yielded mixed results in terms of the significant gains in PSTE and STOE (Hechter, 2011; McKinnon & Lamberts, 2014).

The results from the studies conducted within the context of specially designed content courses (N=15) for PSTs seems positive in terms of their impact on self-efficacy. Studies have identified various supports for PSTs during specialized content courses, including hands-on inquiry (Authors, 2016; 2018; Avery & Meyer, 2012; Gray, 2017), instructor role modeling teaching pedagogies such as learning cycle and argumentation (Authors, 2018; Knaggs & Sondergeld, 2015; Narayan & Lamp, 2010), and instructor enthusiasm (Palmer et al., 2015). Although these findings are promising, the enduring impact on self-efficacy stands undetermined; authors (2018) found that PSTs remained hesitant about their content preparedness. The reinforcement of content learned in methods courses may uphold gains in self-efficacy.

Preservice Engineering Teaching Self-Efficacy: Trends

In exploring the contexts of studies focusing on engineering teaching self-efficacy, we found that four out of eight studies were conducted within semester-long courses. Among the four, only two courses explicitly focused on engineering design, and other associated activities involving Lego Mindstorms EV3 Educational Robotics kits (e.g., Yesilyurt et al., 2021), activities from Engineering is Elementary (EiE®) curriculum (Perkins Coppola, 2019) occurred throughout the semester. Vicarious experiences such as watching videos of expert classroom teachers' engineering instruction and reading children's books on engineering were additional elements of the courses. Other studies discussed two-week interventions focusing on 3D printing (e.g., Kaya et al., 2019) or engineering activities in conjunction with other disciplines, such as science, language arts, and mathematics (Webb & Lofaro, 2020). While five out of eight studies utilized mixed-methods designs, the other three used either quantitative or qualitative methods. Studies used either the Engineering Teaching Efficacy Beliefs Instrument (ETEBI; Kaya et al., 2019) or Teaching Engineering Self-Efficacy Scale TESS (Yoon et al., 2014) to determine the changes in self-efficacy beliefs from the beginning to the end of the semester or after the two-week long intervention. Three out of eight studies found statistically significant differences for both personal engineering teaching efficacy (PETE) and engineering teaching outcome expectancy (ETOE); however, there was a larger effect size for PETE as compared to ETOE. In contrast, Perkins Coppola (2019) found no significant change between ETOE scores from the beginning to the end of the semester; however, the small effect size could be a factor.

Current Gaps and Future Directions

We observed several inconsistencies and issues in the methods employed and findings deserving attention. First, most extant studies on PSTs' science and engineering teaching self-efficacy have been framed within the context of teacher preparation courses that are semester-long or short-term interventions. Although these semester-long studies found positive changes in self-efficacy, it is difficult to claim the achievement as a lasting one. Second, several studies on PST self-efficacy were conducted within science methods courses, at times, the specific contexts in which these experiences occur and contribute to science teaching self-efficacy are insufficiently detailed. An important question arises: How is science and engineering teaching self-efficacy shaped and reshaped over time and across contexts? Third, studies of science and engineering teaching self-efficacy offer inconsistent evidence on the effects of various interventions on PSTE/PETE and STOE/ETOE. A majority of studies on PSTs suggest lesser gains in STOE. Less is known about the challenges to increasing STOE beliefs as compared with PSTE beliefs. Fourth, while there has been increased emphasis on engaging PSTs in engineering practices, the time devoted to engineering in science methods courses is often limited (Webb & LoFaro, 2020). More studies are needed to provide a more comprehensive picture of how engineering teaching self-efficacy develops or sustains over time.

Discussion and Interest to AERA Members

Reflecting on the research findings, we stress that self-efficacy is a powerful construct for deepening our understanding of teacher behavior, motivation, and performance. While studies suggesting increases in PST self-efficacy during training seem promising (Author, 2020; Bleicher, 2017), much remains unclear about developing and sustaining self-efficacy long term. Longitudinal studies across the span of teacher preparation programs not only will help researchers understand how each course impacts PST science and engineering teaching self-efficacy beliefs but may also invite science teacher educators to seek a strategic approach to better integrate topics addressed in various preservice courses (e.g., more-strategic dialogue and discussion between science content and methods course instructors). This presentation will be of interest to AERA members involved in science and engineering teacher preparation and its impact on self-efficacy beliefs. In particular, those with an interest in elementary teaching will find this presentation useful.

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Table 1

Search Terms used for Database Search

Search Term	Location
self-efficacy	Abstract
teach*	Abstract
elementary	All Text
(preservice OR pre-service OR inservice OR in-service)	All Text
(science OR engineering)	All Text

Note. * is used to broaden a search by finding words that start with the same letters. For example, teach* would find teacher, teaching, etc.

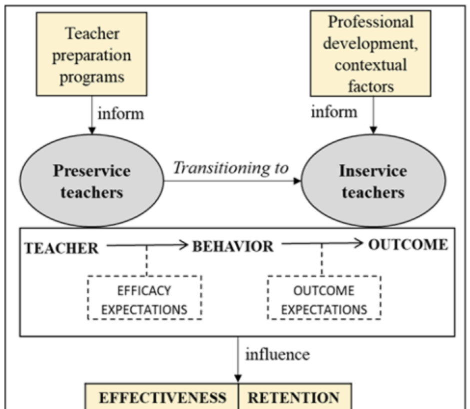
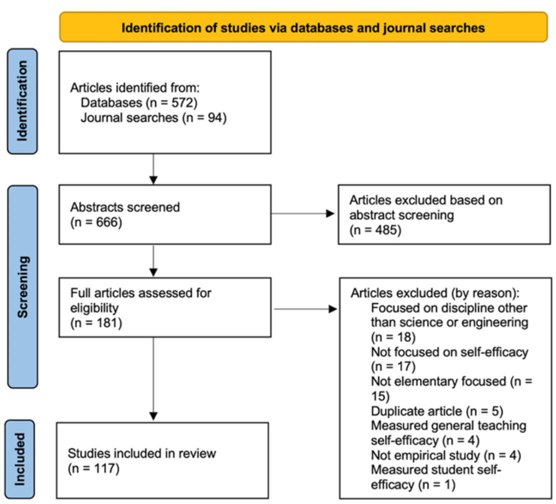


Fig 1. A Research-based Framework for Teacher Self-efficacy



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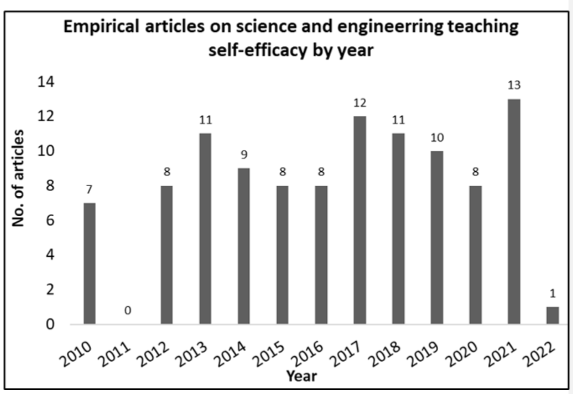

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