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Exploring the relationship between self-efficacy beliefs when teaching science and engineering

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Abstract
The belief that pre-service science teachers can effectively instruct science has been the subject of substantial research. However, a lack of research exists to examine the relationship between pre-service teachers' self-efficacy beliefs and their capacity to teach science and engineering. To fill this void in the literature, it is necessary to investigate the relationship between self-efficacy beliefs in engineering and science education. To address this knowledge deficit, this research investigated the relationship between pre-service science teachers' self-efficacy beliefs in science instruction and their engineering teaching self-efficacy beliefs. The data were obtained from 224 pre-service science teachers using a quantitative approach. The study results indicated that pre-service teachers' self-efficacy beliefs in science teaching were higher than in engineering teaching. The correlation analysis revealed a strong and significant correlation between self-efficacy beliefs in science and engineering teaching. The regression analysis also showed a significant relationship between self-efficacy beliefs in science and engineering. In addition, the results also revealed that science-teaching self-efficacy beliefs explained 52% of the variation in participants' engineering-teaching self-efficacy beliefs. Future research recommendations are derived from the results.

Keywords: science self-efficacy, engineering teaching self-efficacy, self-efficacy beliefs, pre-service teachers

INTRODUCTION

Preparing effective science educators is important to fostering scientifically literate citizens in today's world (Akilli & Kutur, 2023; Sultan, 2020; Sultan et al., 2018). Examining and understanding the self-efficacy beliefs of future teachers has been a focus of research (Britner & Pajares, 2006; Ilhan et al., 2015; Kwami Apoenchir et al., 2023). Science teachers' beliefs in teaching science concepts are known as science-teaching self-efficacy and are a crucial aspect of their professional development (Bandura, 1997; Enochs & Riggs, 1990; Kartal et al., 2022). Self-efficacy refers to an individual's confidence in successfully teaching a particular issue or topic and completing a particular task (Bandura, 1997). They have gained attention as a predictor of teacher effectiveness, instruction, and student outcomes (Ilhan et al., 2015; Kiran, 2022; Sultan, 2020). Science teacher educators need to analyze the complex nature of self-efficacy beliefs and understand their implications for the preparation of aspiring science educators (Kiran, 2022; Uyanik, 2016; Wang et al., 2015). Research has indicated that strong self-efficacy is associated with greater confidence and competence in delivering effective science instruction by teachers (Asilevi et al., 2024; Velthuis et al., 2014; Wang et al., 2015).

The literature provides abundant evidence to substantiate the importance of self-efficacy. Research

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Contribution to the literature

- Although much more research has been done on the science teaching efficacy of pre-service science teachers, there is a notable research gap in exploring cultural and contextual influences on science teaching.
- In addition, the relationship between science teaching self-efficacy and other teacher beliefs, including engineering self-efficacy, has not yet been explored. Therefore, the present study aims to establish a direct relationship between self-efficacy beliefs in teaching science and engineering.
- The results of this study provide a more holistic picture of prospective teachers' readiness to teach science and engineering and their self-efficacy beliefs. Therefore, this research is particularly important for teacher education, professional development and related stakeholders.

findings have revealed that teachers with robust self-efficacy beliefs are more likely to use inquiry-based strategies, incorporate hands-on activities, and adjust their teaching to adapt to the diverse needs of students (Enochs & Riggs, 1990; Seneviratne et al., 2020). Despite the importance of self-efficacy in science education, there is a clear absence of research to understand the complex connection between the efficacy of science teaching and the efficacy of teaching engineering among future teachers. Simultaneously with the emphasis on self-efficacy in science, there has been growing attention to the significance of engineering among educators and policymakers. Integrating engineering practices in science class aligns with modern science education, prioritizing critical thinking, problem-solving, and collaboration (Coppola, 2019; Yoon et al., 2014). Recognizing the need for more informed prospective teachers to integrate engineering into the science classroom, teaching engineering self-efficacy has become an interesting topic for scholars (Lewis et al., 2021; Zhang et al., 2023).

Engineering self-efficacy refers to prospective teachers' belief that they can effectively teach engineering concepts (Utley et al., 2019). As the boundaries between science and engineering become increasingly unclear, educators are challenged to prepare prospective teachers to have a solid understanding of scientific principles and the efficacy of integrating engineering thinking into their science teaching beliefs (Cunningham & Carlsen, 2014). The lack of research highlights a critical gap in our understanding of how prospective teachers perceive their ability to navigate the interplay between science and engineering. While the existing literature is rich in science self-efficacy beliefs (Wang et al., 2015), it often does not provide a holistic perspective incorporating the relationship between science teaching and engineering self-efficacy. Therefore, this research aimed to address this gap by examining prospective teachers' beliefs in both areas and highlighting the intricate relationships between teaching science and self-efficacy in engineering. By conducting this research, the authors contribute to the existing knowledge and provide insights for teacher education program design and implementation. We aim to improve theoretical understanding and provide practical implications for educators, researchers, and policymakers seeking to train science teachers to meet the demands of science and engineering education.

Rationale of Research

Although much more research has been conducted on the science teaching efficacy of pre-service science teachers, several research gaps remain. Firstly, one notable gap is in exploring cultural and contextual influences on science teaching efficacy, as the existing studies are predominantly from Western contexts. Nearly all of the research has been conducted by scholars who work in Western and developed countries. To develop a comprehensive understanding of teachers' self-efficacy beliefs, it is important to investigate how cultural factors shape their efficacy beliefs. Secondly, the relationship between science teaching efficacy and other teacher beliefs, including engineering self-efficacy, has not been explored. Therefore, more research is needed to establish a direct link between self-efficacy beliefs in teaching science and engineering. To bridge this gap, further investigation is necessary to comprehend better the potential correlations, influences, and unique aspects of these two domains of self-efficacy beliefs. Understanding how these beliefs interact can provide a more holistic portrait of prospective teachers' preparedness to meet the diverse challenges of science and engineering teaching. Hence, this research is particularly important for teacher education, professional development, and related stakeholders.

LITERATURE REVIEW

Science Teaching Efficacy Beliefs

Previous researchers have indicated that if someone is confident about their beliefs and skills and expects a favorable outcome, they feel effective in performing the task (Bandura, 1997; Sultan, 2020). Self-efficacy beliefs pertain to teachers' assurance in their aptitude to instruct science effectively. Teaching efficacy beliefs significantly influence teachers' behavior and the strategies they use in their classrooms. Teachers who possess robust self-efficacy beliefs are more likely to exhibit toughness when faced with challenges in the classroom and demonstrate a greater ability to facilitate learning for all students (Enochs et al., 1993; Kartal et al., 2022; Kazempour, 2014; Sultan, 2020). Thus, it can be inferred that teachers with strong self-efficacy are likelier to exhibit high proficiency in teaching science in their classrooms.

Numerous studies have examined the self-efficacy of pre-service science teachers and the related factors influencing their science teaching efficacy. For example, prospective teachers' content knowledge and pedagogical training are critical to science teaching efficacy (Enochs et al., 1993). Also, research suggests that efficacy beliefs change as teachers' understanding of science and teaching strategies improve. In addition, the role of mentorship and field experiences impacts teachers' self-efficacy. Positive interactions with mentor teachers and engaging, hands-on experiences in real classrooms can significantly develop science teaching efficacy (McDonnough & Matkins, 2010). When teachers gain practical experience, they can apply their theoretical knowledge and promote a sense of efficacy.

Pre-service teachers with high science teaching efficacy are likelier to use student-centered and inquiry-based instructional strategies (Riggs & Enochs, 1990). Their efficacy in their capacity to facilitate significant scientific learning encounters results in a readiness to explore inventive pedagogical approaches, establishing an environment that fosters student involvement and comprehension. Conversely, researchers have determined that prospective teachers with lower science teaching effectiveness may rely on traditional and teacher-centered approaches (Riggs & Enochs, 1990). For example, Fazio et al. (2020) found a significant shift from negative to positive beliefs among the students following their participation in the workshop on inquiry-based teaching and the subsequent implementation of a multi-day science fair. In a different research line, scholars explored the impact of various factors on pre-service teachers' beliefs. One of them is their self-efficacy beliefs in meaning engineering.

Teaching Engineering Self-Efficacy

Many scholars have researched pre-service teachers' engineering self-efficacy during the last few years. For example, Hammack and Ivey (2017) evaluated teachers' preparedness levels to implement engineering standards. The study revealed that teachers had low engineering self-efficacy and engineering teacher efficacy. Zhang et al. (2023) studied the self-efficacy of Chinese technology teachers in teaching engineering. Their findings indicated that most technology teachers lacked confidence in teaching engineering. They also found that the research findings revealed that teachers who attended six or more in-service training events had higher self-efficacy in teaching engineering than those who had not. On the other hand, teachers who had never attended any in-service training had lowest self-efficacy.

The study by Perkins Coppola (2019) created a science methods course to offer students hands-on experience in the engineering design process and enhance their self-efficacy in teaching engineering subjects. The study revealed a significant increase in self-efficacy scores across three out of the four constructs of the engineering teaching self-efficacy scale. Smetana and Nelson (2023) conducted a study to assess the efficacy of a course on teaching methods for elementary engineering. The study examined the course's influence on teacher candidates' self-efficacy in instructing engineering in primary school settings. The study's findings demonstrated that the teacher candidates who participated exhibited elevated efficacy beliefs and increased confidence in their comprehension and mastery of elementary engineering. In a recent research by Nesmith and Cooper (2021), participating in an engineering program positively impacted pre-service teachers' self-efficacy toward engineering. The study found that the pre-service teachers had a moderate to high level of engineering self-efficacy and a moderate level of engineering pedagogical content knowledge.

Lewis et al. (2021) involved ten trainee teachers collaborating with engineering students to design and implement science and engineering tasks. The results showed a significant improvement in the trainee teachers' self-confidence in their subject knowledge and their self-efficacy as teachers. The study conducted by Webb and LoFaro (2020) examined the influence of a method course on the self-efficacy of prospective elementary school teachers to teach engineering practices. Their findings indicated a significant increase in the self-efficacy of elementary school teachers in instructing engineering practices following the completion of the course. In their study, Hammack et al. (2020) examined the effects of a professional development program, specifically targeting the utilization of mathematics and science in engineering. The study demonstrated that the engineering program benefited teachers' engineering and teaching efficacy. A study by Crawford et al. (2021) assessed the efficacy of a program designed to enhance teachers' self-efficacy in teaching engineering. The results showed notable enhancements in teachers' self-efficacy in both groups.

RESEARCH METHODOLOGY

Participants

In this study, a total of 224 pre-service science teachers participated. There were 110 male and 114 female participants, aged between 19 and 24 years old (with an average age of 21.2 and a standard deviation [SD] of .81). They were selected from a public research university, and their real names were not used at any stage of the study to ensure their anonymity. The participants voluntarily agreed to participate. The participants had completed science method courses as

Table 1. Sample items included in data collection instruments

Instruments	Sample items
STEBI	I understand science concepts well enough to be effective in teaching elementary science. When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand it better. If students are underachieving in science, it is most likely due to ineffective science teaching.
TESES	I can discuss how given criteria affect the outcome of an engineering project. I can recognize and appreciate engineering concepts in all subject areas. I can encourage my students to interact with each other when participating in engineering activities.

Table 2. Means (M) & standard deviations (SD) for self-efficacy beliefs

	Number of items	Min	Max	Skewness	Kurtosis	M	SD
Engineering teaching self-efficacy beliefs	23	1	5	.38	-.24	4.04	.69
Science teaching self-efficacy beliefs	23	1	5	.23	-.65	4.24	.85

Table 3. Correlation results between self-efficacy beliefs in science & engineering teaching

		1	2
Pearson correlation	Engineering teaching self-efficacy beliefs	1.000	.723**
	Science teaching self-efficacy beliefs	.723**	1.000

Note. **Correlation is significant at 0.01 level (2-tailed)

part of their teacher education programs at the university and were being trained to become science teachers for primary and middle schools.

Data Collection Tools

Science teaching efficacy belief instrument

Science teaching efficacy belief instrument (STEBI) was developed by Riggs and Enoch (1990) to measure pre-service and in-service teachers' science-teaching self-efficacy beliefs. It is commonly used tool to measure pre-service elementary teachers' self-efficacy in science teaching. It consists of 23 items rated on a Likert scale from one (strongly disagree) to five (strongly agree). The reliability analysis showed good reliability, as evidenced by a Cronbach's alpha of .89 in this research.

Teaching engineering self-efficacy scale

Yoon et al. (2014) developed the teaching engineering self-efficacy scale (TESES). It consists of 23 items distributed across four factors. It has a Likert type, from one strongly disagree to five strongly agree. The results demonstrated good reliability. We found that Cronbach's alpha score was .93. **Table 1** shows sample items for data collection instruments.

Data Collection

The scales were accessible to the participants through a Google Form link. The instruments were administered to the participants, and data collection tools were completed in around thirty minutes.

Data Analysis

After completing the questionnaires, the responses were entered into SPSS software for quantitative analysis. We checked normality and other correlation assumptions. After finding that the data showed a normal distribution, researchers looked at simple scatter plot results using SPSS program to check their suitability for the linear regression analysis. The results showed that the data was suitable to run the regression analysis for the data in this study. Later, after the regression analysis, results demonstrated that Cook's distance was .06. Thus, all regression analysis assumptions were met. Also, during analysis, we performed correlation analysis to obtain answers to the research questions. We used linear regression analysis to find relationship between teaching self-efficacy in science and engineering.

RESULTS

Table 2 presents mean and SDs for participants' science and engineering teaching self-efficacy beliefs. The results revealed that pre-service teachers' science-teaching self-efficacy beliefs had higher mean scores than engineering-teaching self-efficacy beliefs. In addition, the mean scores are higher than four on average. This result means that the participants had higher mean scores regarding their science and engineering teaching self-efficacy beliefs. Furthermore, SDs in pre-service teachers' science-teaching self-efficacy beliefs had higher mean scores than engineering-teaching self-efficacy beliefs.

Table 3 shows the results of correlation analysis to examine the relationships between pre-service teachers' science and engineering teaching self-efficacy beliefs. According to the results of correlation analysis, significant relationships were found between pre-service teachers' science and engineering teaching self-efficacy beliefs (.723, $p<.05$). This relationship is strong because the correlation number is higher than .70. Namely, it can be concluded that when the participants' science

Table 4. Results of a simple regression test

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	2.418	1	2.418	242.796	<.001[b]
	Residual	2.211	222	.010		
	Total	4.630	223			

Note. [b]Predictor: Science teaching self-efficacy beliefs

Table 5. Coefficients of determination model summary

Model	R	R square	Adjusted R square	Standard error
1	.723[a]	.522	.520	.099

Note. [a]Predictors: (Constant), science teaching self-efficacy beliefs

Table 6. Regression line equation coefficients

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Standard error	Beta		
1	(Constant)	1.119	.188		5.955	<.001
	Science teaching self-efficacy beliefs	.690	.044	.723	15.582	<.001

Note. [a]Dependent variable: Engineering teaching self-efficacy beliefs

teaching self-efficacy beliefs increase their engineering teaching self-efficacy beliefs.

Table 4 shows that a simple regression test on the relationship between pre-service teachers' science and engineering teaching self-efficacy beliefs yielded significant results ($p<.05$, $F=242.796$). This result means that a significant p-value is smaller than a .05 value, and it can be concluded, based on the obtained statistical result, that the participants' science teaching self-efficacy beliefs variable significantly affected their engineering teaching self-efficacy beliefs. Namely, the science teaching self-efficacy beliefs variable can be used strongly to predict engineering teaching self-efficacy beliefs.

Table 5 shows the results of the coefficient values in the linear regression analysis. According to these results, the R-value shows the number 0.723, which has a positive impact. Also, it was found that the R-value squared of 0.52 indicates the magnitude of the regression model resulting from the interaction of two variables, including independent and dependent variables, namely the relationship between pre-service teachers' science and engineering teaching self-efficacy beliefs. With the coefficient value calculated as 52%, it can be concluded that the independent variable (science teaching self-efficacy beliefs) contributes 52% to the dependent variable (engineering teaching self-efficacy beliefs). Namely, the amount of variance in science teaching self-efficacy that accounted for engineering teaching self-efficacy beliefs. Briefly, science teaching self-efficacy explained 52% of the variation in participants' engineering teaching self-efficacy beliefs. This result means that science teaching self-efficacy predicted engineering teaching self-efficacy beliefs.

Table 6 shows a significant relationship between pre-service teachers' science and engineering teaching self-efficacy beliefs among pre-service teachers. **Table 6** shows the unstandardized constant coefficient as 1.119. This number is constant, meaning that if the participants' science-teaching self-efficacy beliefs (X) increase, the engineering-teaching self-efficacy beliefs will increase. In this case, it was found that the regression coefficient was .690, meaning that for every 1% addition of multicultural education (X), student tolerance (Y) will lead to a decrease by .690. The regression line equation based on **Table 6** is $Y=1.119+0.690*X$, meaning that science teaching self-efficacy beliefs (X) have a positive and significant relationship to engineering self-efficacy beliefs (Y).

DISCUSSION

The present study examined the relationships between self-efficacy beliefs and science and engineering teaching. In pursuit of this objective, this study explored whether engineering teaching self-efficacy beliefs in PSETs are predictive of science teaching self-efficacy beliefs. Overall, the mean scores revealed that pre-service teachers' science-teaching self-efficacy beliefs had higher mean scores than engineering-teaching self-efficacy beliefs. The correlation analysis between the self-efficacy beliefs of prospective science and engineering teachers revealed a strong and significant relationship between these two variables. Linear regression test results also showed a significant relationship between the self-efficacy beliefs. This result means that participants' self-efficacy beliefs significantly influence their beliefs about teaching engineering. Furthermore, the results indicated that participants' teaching science self-efficacy beliefs explained 52% of the variance in participants' engineering teaching self-efficacy beliefs.

Our results showed that teachers' self-efficacy in teaching science and engineering positively correlated. This result is a new knowledge in research on pre-service teachers' self-efficacy beliefs. Regarding the relationship between science and engineering teaching self-efficacy beliefs, one possible reason may be that teacher education programs typically emphasize science over-engineering, leading to greater self-efficacy in science teaching. As it may be well known, engineering is relatively new to the K-12 curriculum, and pre-service teachers may not have studied it as extensively during their education or teacher training. Another reason may be that although there are best practices for teaching science, teaching methods for engineering may be less established or standardized, leading to uncertainty and lower self-efficacy. Pre-service teachers may gain more confidence in teaching science subjects due to their hands-on experience with science experiments and activities during teacher education programs. However, lacking practical experience in designing engineering projects and problem-solving can lead to lower self-efficacy in teaching engineering subjects compared to science self-efficacy beliefs. Perhaps misconceptions or stereotypes about teaching engineering concepts and engineering education may have impacted the participants' self-efficacy. On the other hand, if they do not have a strong identification with engineering, they may not feel confident teaching it effectively. In conclusion, based on our result, developing interventions and professional development programs can balance the self-efficacy beliefs of science and engineering teachers-in-training and establish a correlation between them. For example, Coppola (2019) found that combining engineering design activities with explicit-reflective instruction improved the engineering teaching efficacy beliefs of pre-service teachers. Moreover, the study by Celik and Ergin (2022) pointed out that the perception of the teaching profession can also influence one's self-efficacy beliefs in teaching science and engineering.

As science teaching is more embedded in pre-service curricula, these teachers may have had more opportunities to have such experiences in science than in engineering. Many research investigations have demonstrated that including teaching practice courses and supplementary educational courses can substantially influence pre-service teachers' self-efficacy beliefs (Sultan et al., 2018). Research has also examined the impact of educational interventions on pre-service teachers' self-efficacy beliefs. For example, an inquiry-based science course improved pre-service elementary teachers' self-efficacy in science and willingness to teach it in their future careers (Avery & Meyer, 2012). Furthermore, activities such as field experiences, peer teaching, and self-evaluation of microteaching have been suggested as effective ways of improving self-efficacy beliefs (McDonnough & Matkins, 2010). Similarly, Irmak and Ozturk (2022) found that pre-service science teachers' views about engineers and engineering become more knowledgeable after completing a STEM degree course specializing in engineering.

The results revealed from this present research acknowledge the importance of developing pre-service science teachers' science-teaching and engineering self-efficacy beliefs. Researchers have suggested several influential factors in developing science teachers' science-teaching self-efficacy beliefs. For example, Velthuis et al. (2014) found that primary school teachers who perceived themselves as having greater expertise in the subject matter and more experience in teaching science tended to have higher personal confidence in their ability to teach science. Simsar and Davidson (2020) explored that pre-service teachers' physiological and emotional states significantly impacted their self-efficacy beliefs regarding science and science teaching. The findings of Hsin et al. (2022) revealed that teachers' proficiency in teaching, perception of social assistance, and attitude toward instructing a diverse student population significantly and positively impacted their confidence in teaching science and their expectations for student outcomes. Regarding changing engineering teaching self-efficacy beliefs, Ivey et al. (2016) found the influence of self-efficacy on teacher engagement and learning outcomes associated with specific contexts. The present research and previous findings highlight the importance of targeted interventions to enhance pre-service teachers' self-efficacy in science and engineering teaching.

CONCLUSIONS

This paper explored the relationships between science and engineering teaching self-efficacy beliefs. The results demonstrate that science teaching self-efficacy beliefs predicted engineering teaching self-efficacy beliefs. The results from this research present new knowledge for researchers and contribute to the research literature. With the integration of engineering and science education in education, it is essential to understand and support the development of these beliefs. Our research has several conclusions. Firstly, pre-service teachers' science and engineering self-efficacy beliefs can be enhanced during certain stages of their training by emphasizing the possibility of increasing and advancing their self-efficacy beliefs over time. Secondly, we suggest that various factors, such as knowledge, experiences, metacognitive skills, emotional states, and instructional practices, can influence engineering teaching self-efficacy beliefs by interacting differently. Understanding these dynamic relationships is critical for teacher educators because it underscores the need for targeted interventions to strengthen beliefs about teaching effectiveness and ultimately influence instructional decisions in favor of more effective engineering and science teaching practices.

RECOMMENDATIONS

Based on the results, future studies should investigate the role of instructional strategies in enhancing self-efficacy in science classrooms. In addition, longitudinal studies could add new contributions to scholars' knowledge about how self-efficacy beliefs develop throughout teacher education programs. Our findings underscore the need for more integrated engineering experiences for teacher education. Teacher education may improve self-efficacy by incorporating hands-on engineering projects and problem-based learning. In addition, future studies must prioritize investigating the variables that can impact teachers' self-efficacy in science and engineering. Furthermore, many resources are available for teaching science with engineering concepts, including textbooks, lab equipment, and professional development opportunities. These can provide unique opportunities for developing pre-service teachers' self-efficacy beliefs.

Limitations

The results of this study have some limitations. Firstly, the study employed a limited sample size of teachers. Secondly, only pre-service teachers were the focus of this investigation. Additional research is necessary to explore the relationship between self-efficacy in science and engineering.

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