Journal of Research in Science, Mathematics and Technology Education

https://jrsmte.com/

Examining Growth in Preservice Science Teaching and Learning Self-Efficacy Using Mixed Methods

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Abstract: Tuning in to preservice teachers' self-efficacy for science learning and teaching allows teacher educators to construct meaningful learning experiences to build motivation and pedagogical skills in science methods courses. While literature on science teaching efficacy is robust, research focusing on how preservice teachers' beliefs about themselves as science learners, in conjunction with their beliefs as science teachers, has yet to be adequately addressed. This study used a convergent mixed methods approach to address this gap by examining how preservice teachers' self-efficacy for learning science evolves alongside their self-efficacy for teaching science. Preservice teachers enrolled in an elementary science methods course completed instruments assessing their beliefs in their ability to learn science and their beliefs in their ability to teach science at the beginning and end of the semester. In addition, preservice teachers completed reflective science autobiographies. Results from quantitative and qualitative data sets confirmed significant increases in preservice teachers' self-efficacy towards learning and teaching science after participating in and creating phenomena-based elementary science lessons. Implications for teacher education include embedding reflective activities into courses and purposefully tuning in to preservice teachers' beliefs to best support and scaffold the development of confident science learners and teachers.

Keywords: Science efficacy; Science teaching efficacy; Preservice teacher education; Elementary education; Mixed methods
DOI: https://doi.org/10.31756/jrsmte.912

Introduction

The evolution of science education from traditional to constructivist pedagogies marks a significant paradigm shift observed across many national contexts (Barak, 2016; Kar & Sahu, 2025; Ulukütük, 2022). For example, the publication of *A Framework for K-12 Science Education* (National Research Council, 2012) introduced the framework of three-dimensional science instruction in the United States. While many educators worldwide may recall science classrooms focused on rote memorization, passive note-taking, and teacher-centered delivery of facts and procedures, contemporary reforms promote a constructivist model that requires students to collaboratively act (i.e., science and engineering practices) and think like scientists (i.e., crosscutting concepts) while exploring content (i.e., disciplinary core ideas). Thus, fostering a deeper understanding of the process, potential, and limitations of science. Considering these shifts, we must prepare teachers to plan, facilitate, and manage inquiry-rich, multidimensional science classrooms across diverse educational systems.

A proactive approach to preparing preservice teachers (PSTs) involves ensuring that course objectives are relevant to the perspectives and experiences of the student participants. In the United States, women make up 89% of teachers in public elementary schools (National Center for Educational Statistics, 2023). Given the international gender stereotyping of males in STEM roles among students and adults (Chambers, 1983; Master et al., 2025; Miller et al., 2018) and its effect on motivation (Master, 2021; Starr & Simpkins, 2021), focusing on female PSTs' beliefs about their abilities to learn science (i.e., self-efficacy for learning science) has the potential to be an effective intervention for increasing the quality of elementary science teaching.

Self-Efficacy for Learning Science

Rooted in social-cognitive theory (Schunk & DiBenedetto, 2020), self-efficacy refers to an individual's belief in their ability to perform particular tasks or roles to achieve a desired outcome (Bandura, 1977, 1997). Individuals develop self-efficacy across various domains and skills, such as academic, social, and occupational (Zimmerman, 2000). In the context of teacher preparation, PSTs represent a unique population of learners because they must simultaneously develop their self-efficacy as learners of pedagogical and content knowledge while also considering their professional identity (Tschannen-Moran & Hoy, 2001).

Self-efficacy for learning refers to an individual's belief in their capabilities to acquire new knowledge or skills in specific content areas (Schunk & Pajares, 2002). Researchers have found that self-efficacy for learning science is an important contributor to academic engagement, persistence, and performance as well as post-graduation outcomes, such as career intentions and life satisfaction (DiBenedetto & Bembenutty, 2013; Robinson et al., 2022). Interestingly, self-efficacy for learning is a dynamic construct that can fluctuate over time in response to various academic and emotional experiences. Rather than remaining static, students' beliefs about their ability to learn science may change positively or negatively over a single academic semester (Ainscough et al., 2016; DiBenedetto & Bembenutty, 2013).

Self-Efficacy for Teaching Science

Self-efficacy for teaching can be defined as teachers' beliefs about their capabilities to affect student learning and performance (Tschannen-Moran et al., 1998). Researchers have distinguished between teaching self-efficacy and teaching outcome expectancies, the latter referring to teachers' beliefs about the extent to which their teaching can positively influence students' learning (Tschannen-Moran et al., 1998). High teaching self-efficacy can lead to greater persistence, enthusiasm, and willingness to implement innovative teaching strategies (Tschannen-Moran & Hoy, 2001). Conversely, low teaching self-efficacy can make teachers reluctant to adopt new methods, potentially hindering educational reform efforts (Gibson & Dembo, 1984). Therefore, teacher education programs need to focus on building strong teaching self-efficacy beliefs among PSTs to ensure they are well-equipped to handle the current demands of science education (Bergman & Morphew, 2015).

To effectively build science teaching self-efficacy in teacher education, teacher educators must remain attuned to the perceptions and experiences that PSTs bring into science methods courses. PSTs often enter these courses with pre-established relationships and beliefs about science that can both positively and negatively influence their content knowledge, science literacy, and attitudes toward teaching science (Gagnier et al., 2022; Hulings, 2022; Knaggs & Sondergeld, 2015). These preconceptions may manifest in varying confidence, anxiety, and motivation levels, shaping their development as future science teachers.

Fostering strong science teaching self-efficacy is important, as it empowers PSTs to deliver high-quality science instruction that supports student engagement and achievement (Kazempour & Sadler, 2015). However, there is mixed evidence on how PSTs' science teaching self-efficacy evolves throughout teacher preparation. Some studies have found that while teaching self-efficacy may increase throughout a science methods course, PSTs' outcome expectancies—their beliefs about the effectiveness of their teaching influencing student learning—may simultaneously decline (Cantrell et al., 2003). In contrast, other research suggests a positive relationship between the two (Bleicher & Lindgren, 2005; Menon & Sandler, 2016). The mixed findings illustrate a gap in the literature identifying impactful learning opportunities to incorporate into science education teacher preparation courses.

Although the Next Generation Science Standards (NGSS Lead States, 2013) and the framework for three-dimensional science instruction have been available for over a decade, many elementary in-service teachers in the United States still report feeling unprepared to teach science effectively (Banilower et al., 2018). This lack of preparedness and increased science anxiety among teachers has been shown to significantly impact the science anxiety levels of elementary students coming from a low socioeconomic status (McLean et al., 2023).

The present study aimed to investigate PSTs' self-efficacy for learning and teaching science. Developing a deeper understanding of instructional practices that enhance self-efficacy in learning and teaching science may enable teacher educators to better prepare future teachers. This preparation is crucial for navigating the challenges of implementing reform-based practices within the increasingly limited time allocated for daily science instruction in elementary classrooms (Banilower et al., 2018). Additionally, teacher educators may be better equipped to support elementary students' interests and achievement in science (Fauth et al., 2019).

Developing Learning and Teaching Self-Efficacy

Researchers have highlighted various instructional strategies that can be embedded into science methods courses to support the development of science teaching self-efficacy (Ibourk & Mathis, 2024; Kartal & Dilek, 2021; Novak & Wisdom, 2018). In alignment with social cognitive theory, these approaches are rooted in the sources of self-efficacy proposed by Bandura (1997) and include: (1) mastery experiences (e.g., collaborative lesson planning, group discussions), (2) vicarious experience (e.g., observing others engage in the task), (3) social persuasion (e.g., positive feedback), and (4) physiological and emotional states (e.g., ability to handle stress and anxiety while teaching).

A prevalent strategy in literature to enhance PSTs' teaching self-efficacy involves offering opportunities to engage PSTs "with activities that make them reflect on their performances, artifacts, or lesson plans" (Kartal & Dilek, 2021, p. 725). Activities that prompt PSTs to reflect on their experiences in science methods courses may be an effective way to support self-efficacy because of their strong connection to the four sources. For instance, reflective journaling can enable PSTs to revisit and analyze their prior instructional successes and challenges, thereby reinforcing mastery experiences that are central to building self-efficacy (Tschannen-Moran & McMaster, 2009). Furthermore, writing teaching philosophies can encourage PSTs to articulate their evolving beliefs and practices, while also reframing PSTs' anxieties about science instruction (Loughran, 2002).

While the literature for examining strategies to strengthen PSTs' science teaching self-efficacy exists (e.g., Bleicher, 2006; Menon & Sadler, 2017; Menon et al., 2025), fewer studies have been conducted exploring how Bandura's (1997) sources of self-efficacy can be used to enhance PSTs' self-efficacy for learning and teaching science. The present study strategically integrates dialogic reflective activities throughout a semester-long elementary science methods course to explore how PSTs' self-efficacy for learning and teaching science evolved.

Present Study

Developing strong self-efficacy in both learning and teaching content is essential for PSTs, as self-efficacy beliefs are closely linked to academic success, teaching effectiveness, and addressing systemic challenges in STEM fields (Bandura, 1997; Sellami et al., 2024; Tschanen-Moran & Hoy, 2001). We report on the following research questions: 1) How do elementary PSTs' beliefs about learning science change over the course of a one-semester methods course? and 2) How do elementary PSTs' beliefs about teaching science change over the course of a one-semester methods course?

Methods

Participants

PSTs across three undergraduate elementary science methods courses engaged in reflective activities over the course of a semester-long elementary science methods course. All participants (*N* = 61) were elementary PSTs seeking teaching certification for grades K–5. Most participants self-reported their gender as female (93%) and their race as white (72%). The average age of the PSTs was 22 years old (*SD* = 3.5). Additional details about participant demographics can be found in Table 1.

Table 1

Demographic Characteristics of Participants

		Number of Participants	Percentage of Participants
Gender			
	Women	57	93%
	Men	1	2%
Race			
	White	44	72%
	Black or African American	10	16%
	Multiracial	3	5%
	Unsure	1	2%
Ethnicity			
	Hispanic or Latinx	2	3%
	Not Hispanic or Latinx	56	92%

Note. N = 61. 5% of participants did not disclose demographic information.

Procedures

We employed a convergent mixed methods design to generate comprehensive findings to deepen insights into the transformative shifts in PSTs' beliefs about science learning and teaching. Using this approach allowed us to capture the development of self-efficacy and other related beliefs about science learning and teaching. Quantitative and qualitative data were collected separately and analyzed independently before being merged to identify areas of convergence and divergence between the datasets (Creswell & Plano Clark, 2017).

Following approval from Georgia Southern University's Institutional Review Board (protocol H24019), data were collected across three elementary methods courses. At the beginning of the semester, the first and second authors shared details about the study during class time, and PSTs were invited to participate. All participating PSTs provided signed consent forms, and numerical data were collected exclusively from individuals who had given free and informed consent. During the first two weeks of the semester-long course, PSTs completed a Likert-scale survey (Survey 1) and Science Autobiography (A1). During week 16 of the course, PSTs completed a second survey (Survey 2) and revised their initial Science Autobiography (A2). Surveys were collected via Qualtrics, while Science Autobiographies were collected through the D2L course management system.

Course Context

Data collection occurred regularly throughout a semester-long, in-person Elementary Science Methods course (three sections) taught by the first and second authors at the same university. At our university, PSTs typically complete this course during the first semester of their senior year. Each section meets twice weekly for 2.5-hour class periods over an 8-week period. While the course primarily emphasizes pedagogy, science content knowledge is integrated through modeled lessons. Reflective activities are strategically embedded throughout the course to prompt PSTs to reflect on their teaching and learning experiences with science, both within and beyond the classroom context.

Quantitative Measures

Science Learning Self-Efficacy

To better understand the PSTs' science learning self-efficacy, we administered the five-item Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S; Thomas et al., 2008). The instrument measured PSTs' beliefs about their ability to complete college science courses. The PSTs reported the extent to which they agreed with items on a five-point scale. In this study, the scale demonstrated good reliability on Survey 1 ($\alpha = 0.91$) and Survey 2 ($\alpha = 0.92$).

Science Teaching Outcome Expectancies and Science Teaching Self-Efficacy

To assess the PSTs' science teaching outcome expectancies and science teaching self-efficacy, we administered the Science Teaching Efficacy Belief Instrument for Preservice Teachers (STEBI-B; Enochs & Riggs, 1990). The Likert-style instrument was slightly modified to align with the study context, particularly in relation to PSTs' prior teacher education coursework and field experiences. PSTs responded to the extent to which they agreed or disagreed with statements using a five-point scale.

Science teaching outcome expectancies were measured using 10 items that evaluated the extent to which PSTs perceived a teacher's role as impacting students' science knowledge. Although prior studies have provided evidence of reliability for this subscale (e.g., Enochs & Riggs, 1990), the calculation of Cronbach's alpha indicated low reliability for Survey 1 ($\alpha = 0.60$) and Survey 2 ($\alpha = 0.59$). After re-evaluating the items, the authors decided that the reversed items may have confused participants. Thus, the reversed items were removed, and the Cronbach's alpha was recalculated. The revised scale, which included eight items, demonstrated adequate reliability on Survey 1 ($\alpha = 0.75$) and Survey 2 ($\alpha = 0.77$).

Science teaching efficacy was measured using 13 items that assessed PSTs' beliefs in their ability to teach science. In the present study, Cronbach's alpha demonstrated adequate reliability on Survey 1 ($\alpha = 0.78$) and Survey 2 ($\alpha = 0.83$).

Qualitative Measures

Science Autobiography

During the first two weeks of the course, the PSTs completed a Science Autobiography assignment (see Appendix A). The assignment provided space for PSTs to: (1) introduce themselves to the instructor, (2) reflect on past experiences learning and teaching science, and (3) develop a philosophy of teaching science within the context of national and state standards. After the semester-long course, PSTs revisited their initial responses and reflected on whether their beliefs had evolved. To examine any shifts in their beliefs, we extracted the PSTs' answers to Questions 2 and 6 from the initial (A1) and final (A2) Science Autobiography assignments. Thematic analysis of these responses provided insights into PSTs' changes in motivations to teach and learn science.

Data Analysis

In accordance with standard practice in convergent mixed methods research (Creswell & Plano Clark, 2017), we conducted quantitative and qualitative analyses concurrently to develop a deeper understanding of PSTs' beliefs about learning and teaching science. We then used the quantitative and qualitative datasets to identify common patterns, which allowed us to confirm, disconfirm, or expand upon the findings from each method. In the following sections, we provide an overview of our approach to each analysis set.

Quantitative Analysis

As an initial step in quantitative analysis, we conducted descriptive statistics. Since we intended to conduct three paired-sample t-tests to investigate shifts in self-efficacy for science learning and teaching over the semester, we also tested the assumptions relevant to t-tests. Next, we conducted a bivariate correlation analysis to investigate the relations between all study variables. Finally, when the data satisfied the assumptions, we conducted paired-sample t-tests.

Qualitative Analysis

To ensure the rigor and trustworthiness of the thematic analysis, the first and second authors engaged in a systematic and collaborative coding process. Initially, both authors independently reviewed and open-coded the dataset to identify emergent themes, allowing for diverse interpretations of the data and thereby reducing the potential for individual bias (Nowell et al., 2017). Then, the two authors met iteratively to discuss the observed patterns, collaboratively refining and reconciling the first- and second-level codes to develop a shared coding framework (Braun & Clarke, 2006).

Following consensus on the coding scheme, the dataset was divided between the two authors, who applied the agreed-upon codes to their respective portions of the dataset. To enhance interrater reliability, each author cross-checked a subset of the other's coded data. Discrepancies were discussed and resolved collaboratively, ensuring consistency and coherence across the entire dataset to strengthen the dependability of the analysis (Miles et al., 2014).

To further strengthen confirmability and triangulation, the researchers integrated the quantitative and qualitative datasets to identify patterns that either confirmed, contradicted, or expanded upon the findings from each source. This data integration process enabled a critical examination of convergences and divergences across the datasets, resulting in a more nuanced and trustworthy interpretation of the results (Creswell & Plano Clark, 2017).

Findings

Quantitative results revealed increases in self-efficacy for learning science, science teaching outcome expectancies, and self-efficacy for teaching science. Qualitative results revealed a more nuanced understanding of the shifts that occurred. In addition, they allowed us to unpack the data to understand individual cases where shifts did not occur. In the following sections, we discuss the findings related to the research questions.

Research Question 1: How do elementary PSTs' beliefs about learning science change over the course of a one-semester methods course?

Initial descriptive statistics highlighted that the mean scores for PSTs' reported science efficacy across both time points were greater than 3.00, meaning that the PSTs tended to agree or strongly agree with the survey items. Bivariate correlations revealed that self-efficacy for learning science at the beginning and end of the semester were positively correlated ($r = 0.61$, $p < 0.01$), meaning that PSTs who reported high self-efficacy for learning science at the beginning of the semester also tended to report high self-efficacy for learning science at the end of the semester (see Table 2).

Table 2

Bivariate Correlations for All Study Variables

Variable	1	2	3	4	5	6
1 Science Teaching Outcome Expectancy (S1)	-					
2 Science Teaching Outcome Expectancy (S2)	0.43**	-				
3 Science Teaching Efficacy (S1)	0.17	0.05	-			
4 Science Teaching Efficacy (S2)	0.06	-0.08	0.40**	-		
5 Science Efficacy (S1)	0.13	0.11	0.55**	0.14	-	
6 Science Efficacy (S2)	-0.03	0.32*	0.34*	0.9	0.61**	-

Note. * = $p < 0.05$, ** = $p < 0.01$

To examine the change in self-efficacy for learning science across the semester, we conducted a paired-sample t-test (see Table 3). Participants were excluded from this analysis if they did not complete both Survey 1 and Survey 2. When testing the assumptions before examining the change in science teaching efficacy, outliers were identified and removed from the data set ($n = 3$) by examining a box plot of the difference between the two time points. Results indicated a statistically significant difference between participants' self-efficacy for learning science at the beginning and end of the semester (t (45) = -7.07, $p > 0.001$); self-efficacy for learning science increased from Survey 1 ($M = 3.13$, $SD = 0.91$) to Survey 2 ($M = 3.97$, $SD = 0.89$). Cohen's d indicated a large effect size ($d = 0.80$). Taken together, the quantitative findings suggest that PSTs felt more capable of learning science concepts at the end of the semester when compared to the beginning of the semester.

At the beginning of the semester, qualitative data revealed that only 12 PSTs (19.6%) indicated high self-efficacy for learning science, often crediting a general appreciation for science or positive past experiences, such as "my teacher from high school" (PST 10) or being "fascinated by my surroundings" (PST 58). In contrast, 28 PSTs expressed low self-efficacy in learning science, with some ($n = 12$) holding traditional, static views of the subject, such as describing it as "more fact-based" (PST 45), "textbook stuff" (PST 15), and involving "memorizing facts" (PST 21).

In the A2 reflection, traditional perspectives on the nature of science decreased by 100% ($n = 0$), while constructivist views increased by nearly 50% ($n = 21$). PST 6 explicitly reflected on how her perspectives "changed drastically" from believing there were "concrete things I must know" to ending the course knowing that she can proactively "heighten [her] thinking" by giving herself "the opportunity to investigate and collaborate with individuals about the concepts as well as research evidence" to understand science concepts better.

Table 3

Paired-Sample T-Tests to Examine Change Across the Semester

Variable	Time 1		Time 2					
	M	*SD*	*M*	*SD*	*t*	df	*p*	Cohen's d
Science Teaching Outcome Expectancy	3.63	0.48	3.91	0.51	-3.83	45	> .001	0.51
Personal Science Teaching Efficacy Belief	3.56	0.42	4.01	0.43	-7.50	41	> .001	0.39
Science Efficacy	3.13	0.91	3.97	0.89	-7.07	45	> .001	0.80

Another notable shift from A1 to A2 was the PSTs' understanding of how science works. For instance, PST 3 noted that learning to "ask questions" has made her "more excited to learn and teach science," while PST 21 described a shift from "memorizing facts to experimenting to find facts." This reframing reflects a growing recognition of science as an evolving, evidence-based discipline. However, not all PSTs experienced increased self-efficacy; PST 19, for example, acknowledged her shift in thinking from science having "only one solution, but in reality, it is investigation upon investigation," which left her feeling as if it was "still hard for [her] to wrap [her] head around." Despite this challenge, most PSTs demonstrated meaningful growth in understanding the processes of science, marking a positive trajectory in their development as science learners.

From A1 to A2, there was a 110% increase (n = 40) in instances from those who saw themselves as capable of learning science and a 67% (n = 10) decrease in those who did not see themselves as capable of learning science. In the A2 reflection, PSTs explicitly discussed the change they underwent sharing, "I see myself more as a science person after this course than before" (PST 19), and "In the original response, I said I never saw myself as a science person… Now at the end of the semester, the idea has changed, and I really do see myself as a science person" (PST 21).

Research Question 2: How do elementary PSTs' beliefs about teaching science change over the course of a one-semester methods course?

To better understand the PSTs' beliefs about teaching science, we investigated science teaching self-efficacy and science teaching outcome expectancies. Mean scores on each scale revealed that PSTs tended to agree or strongly agree with statements regarding their science teaching self-efficacy and outcome expectancies (*M*s > 3.00). Bivariate correlations indicated a significant positive relationship between science teaching self-efficacy at the beginning of the semester and the end of the semester ($r = 0.40$, $p < 0.01$), meaning PSTs who reported high science teaching self-efficacy at the beginning of the semester tended to report high science teaching self-efficacy at the end of the semester (see Table 2). Similarly, the relationship between science teaching outcome expectancies at the beginning and end of the semester was also significant ($r = 0.43$, $p < 0.01$). Both correlations were moderate, indicating that, although PSTs' beliefs were related, they differed at the semester's beginning and end.

We conducted two paired-sample t-tests to investigate the change in teaching beliefs over the semester. Findings revealed statistically significant differences in science teaching self-efficacy and science teaching outcome expectancies. More specifically, results indicated a statistically significant increase in PSTs' reported self-efficacy (t (41) = -7.50, $p > 0.001$), where science teaching self-efficacy was 3.56 ($SD = 0.42$) at the beginning of the semester and 4.01 ($SD = 0.43$) at the end of the semester. Cohen's d indicated a moderate effect size ($d = 0.39$). In addition, results indicated a statistically significant difference between participants' science teaching outcome expectancies at the beginning and end of the semester (t (45) = -3.83, $p > .001$). Participants reported a significant increase in science teaching outcome expectancies from Survey 1 ($M = 3.63$, $SD = 0.48$) to Survey 2 ($M = 3.91$, $SD = 0.51$). Cohen's d was 0.51, indicating a moderate effect size. These findings indicate clear growth in PSTs' beliefs about their teaching.

Qualitative themes revealed that at the beginning of the semester, only 10 PSTs (16.39%) expressed positive self-efficacy for teaching elementary science, often citing the importance of science for students or aspirations for engaging in meaningful instruction. For example, PST 11 emphasized science is "something students need to know," while PST 50 aimed to make sure "students are engaged," and PST 2 hoped to make her instruction "fun for students to learn and help them connect to their lives." By the end of the course, the number of PSTs who identified as science teachers more than doubled ($n = 23$), although those who did not also increased ($n = 7$), with one remaining undecided. This dual increase suggests that the course played a role in shaping PSTs' science teacher identities through practice and reflection. For many, the experience affirmed their identity, as PST 35 reflected in A2 that they can "continuously be a student of science as well as a teacher of science," while others, such as PST 40, credited practical application and "seeing students get excited about the activities" to reinforcing her self-efficacy for science teaching.

A central factor in PSTs' identity development was increased confidence in pedagogical "strategies and techniques on how to go about instruction and clarify any misconceptions I may have" (PST 2), highlighting how the course supported content knowledge and the development of student-centered teaching approaches. This growth reinforced many PSTs as capable, evolving science educators. However, for other PSTs, the course experience brought a different kind of clarity, revealing a lack of interest, discomfort, or misalignment with science teaching as a professional focus. Rather than viewing the increase in PSTs who did not identify as science teachers as a setback, this trend can be seen as evidence of enhanced self-awareness. These PSTs were better positioned to critically assess their interests and strengths within the role of a science teacher, which is a valuable outcome.

Moreover, the presence of undecided PSTs by the end of the course suggests that PSTs were leaving the course with a more nuanced and realistic understanding of what it means to be an effective science teacher. Through exposure to the pedagogical complexities of high-quality science instruction, many PSTs could make more definitive and thoughtful decisions about their identity, whether that meant embracing the role or consciously stepping away from it.

In addition to shifts in science teaching self-efficacy, there was a notable increase in PSTs' self-reported interest in teaching science, with expressed instances of interest and excitement rising by 111% ($n = 46$) between their initial (A1) and final (A2) reflections. Early responses emphasized the general importance of science, such as PST 11's transformative evolution from science being "something students need to know" (A1) to later sharing "I get it. It's no longer a foreign concept, nor is it teacher-driven" (A2). These shifts underscore the importance of integrating science learning and teaching to positively impact pedagogical confidence and a genuine interest in science education.

Discussion

The findings from both research questions offer a multifaceted understanding of how PSTs initially conceptualize their roles as science learners and future science teachers. The results from the quantitative and qualitative datasets complement each other, allowing us to identify areas of convergence (similarity) and divergence (difference; see Appendix B). These insights provide a baseline for recognizing existing strengths in their science identity and pinpointing specific misconceptions, uncertainties, or gaps in pedagogical understanding. This foundational knowledge is critical for designing targeted instructional interventions that directly address the needs of PSTs enrolled in elementary science methods courses. Understanding PSTs' initial confidence, engagement, and identity enables teacher educators to design targeted experiences that build on existing strengths while addressing areas for growth. The following sections elaborate on how these findings connect to prior research and provide implications for supporting PSTs in elementary science methods courses.

Shifts in Self-Efficacy for Learning and Teaching Science

Quantitative and qualitative data converged with similar results when identifying shifts in PSTs' self-efficacy for learning and teaching science throughout the semester. Most PSTs experienced increased self-efficacy for learning and teaching science after participating in and designing student-centered, three-dimensional science instruction. Quantitative results indicated a statistically significant increase in PSTs' reported expectancy for success in teaching science, self-efficacy for teaching science, and beliefs in their ability to learn science in college courses. Qualitative results confirmed the findings and provided elaboration on evidence with themes of PSTs developing a more accurate view of the nature of science and reporting a more substantial interest in teaching science. While most quantitative and qualitative data analyses were similar, there were instances where other beliefs and attitudes about science emerged, thereby highlighting the benefits of a mixed methods approach. For instance, one PST did not see herself as a science "person" but did note how she could see herself as a good science teacher for her students due to her new understanding of the process of science.

Prior evidence has suggested the effectiveness of the constructivist lens of three-dimensional science instruction for PST learning (Bleicher & Lindgren, 2005; Boz & Cetin-Dindar, 2023) and attitudes toward science (Riegle-Crumb et al., 2015). This study's quantitative results are consistent with the literature, highlighting significantly positive gains in PSTs' Personal Science Teaching Efficacy and Science Teaching Outcomes Expectancy (Boz & Cetin-Dindar, 2023; Deehan et al., 2019). The more dramatic increase in PSTs' self-efficacy for science teaching growth over science teaching outcome expectancy results is also consistent with empirical literature within the context of undergraduate science methods courses (Menon & Azam, 2021; Menon & Sadler, 2017).

Few studies in the literature provide context for our results regarding PST's science learning self-efficacy. Using PSTs' misconceptions of the process and nature of science can inform teacher educators on using modeled lessons, collaborative lesson plans, microteaching exercises, and reflective activities as rich learning opportunities. Accompanying this instruction should also be opportunities for PSTs to continually reflect on how they self-identify as science learners and teachers. Pre- and post-surveys can justify PSTs' shifts in perspectives. Furthermore, assignments like the Science Autobiography, when completed at various times in a course, can provide opportunities for PSTs to dive deeper into their beliefs and reflect on instances that profoundly impact their transformation as science learners and teachers. Through these experiences, PSTs can develop more positive attitudes towards science learning and a deeper understanding of the process of knowledge construction in science. Future research should extend this work by further examining the connections between PSTs' beliefs about themselves as science learners and teachers. A better understanding of how these beliefs relate to one another may help researchers and practitioners design instructional supports that foster self-efficacy in science methods courses.

Implications

This study provides quantitative and qualitative data that justify the importance of intentionally planning undergraduate science teacher preparation courses to build science learning and teaching self-efficacy, which is especially relevant given the limited professional development novice teachers will receive upon entering the field (Banilower et al., 2018). Moreover, tracking shifts in beliefs and identity over a semester can highlight the transformative potential of three-dimensional science methods courses and provide opportunities for PSTs to observe changes in themselves as capable science learners and competent science teachers. Consequently, there are implications for future research opportunities and practices.

Actively monitoring PSTs' science self-efficacy in learning and teaching science has practical implications. For example, science methods instructors could work to differentiate instruction based on PSTs' self-efficacy, thereby enhancing learning motivation and achievement (Zhao et al., 2021). Specifically, PSTs with lower science teaching self-efficacy can benefit from scaffolded experiences that gradually build content mastery and pedagogical confidence, such as microteaching, targeted feedback, and structured reflections. Conversely, high-efficacy PSTs may be more challenged and motivated through open-ended inquiry and leadership in lesson design and peer teaching, maximizing their potential and contributing to collaborative learning environments.

Furthermore, practical application may also involve using efficacy instruments to inform course adjustments. When a course does not yield measurable gains in PSTs' science teaching self-efficacy, this may indicate a need to revisit instructional design. This may include integrating mastery experiences by providing increased opportunities for authentic science teaching experiences and reinforcing foundational science concepts. Failure to make such adjustments can leave PSTs underprepared and lacking the confidence necessary to teach science effectively, which may, in turn, hinder both their teaching performance and their students' academic outcomes (Bergman & Morphew, 2015; Bleicher & Lindgren, 2005). Future research should explore how modifying instruction based on students' self-efficacy can facilitate motivation and learning.

Limitations

Several limitations of this study should be considered when interpreting the findings. Our sample of PSTs reflected predominantly white women. While the demographics aligned with our elementary undergraduate teacher preparation program, it is important to consider how gender and race may influence these findings. In the future, researchers should explore whether these findings are consistent across different institutions with varied student demographics. Additionally, the open-ended written items may not have allowed researchers to fully unpack the context and meaning behind the participant responses. Future research could expand on these findings by using approaches that allow for additional meaning-making, such as conducting interviews or focus groups. Finally, this study focused on changes in PSTs' beliefs over the course of a single semester. Future research should extend this investigation by conducting longitudinal research to examine how self-efficacy in learning and teaching science evolves as PSTs navigate their early years of classroom teaching.

Conclusion

Overall, PSTs' motivation to learn and teach science positively increased throughout a semester-long science methods course, which focused on three-dimensional science learning and reflective practices. Notably, PSTs transitioned from traditional views of learning and teaching science to constructivist views that align with the reform-based *Next Generation Science Standards* (NGSS Lead States, 2013). Science teacher educators should pay special attention to the beliefs and attitudes PSTs bring into science methods courses to intentionally build opportunities for PSTs to reflect and acknowledge their changing motivations toward science. The PSTs in this study will one day lead classrooms full of elementary students. Those elementary students deserve to see themselves as scientists, which begins with teachers positively modeling genuine curiosity and excitement toward the field.

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Appendix A

Science Autobiography Assignment

Initial Science Teaching and Learning Autobiography

The purpose of this assignment is to provide you with an opportunity to introduce yourself to me and reflect on your experience teaching and learning science. You will also develop your philosophy of teaching science for student understanding in the context of national and local/state recommendations. Respond to the following questions in at least 3-5 sentences in length (double-spaced). Be sure to reference any research you use to support your claims in 7th edition APA.

Section 1: Introduction/Background

It is important for me to get to know you. Collecting information about you allows me to learn about your interests and what you hope to gain from being in this course. Respond to the following questions so I can get to know you. See the sub-questions as helpful prompts to guide your answers.

1. Who are you? How would you describe yourself?
   a. *What made you choose a degree in education?*
   b. *Are you involved in clubs or activities?*
   c. *Do you have specific grades you do or do not want to teach in the future?*
2. What do you hope to gain from being in this course?

Section 2: Your Experience Learning Science

I want to learn about your experience learning science. One way to do this is by having you reflect on your prior learning experiences and academic needs. Think back to your experiences learning science and respond to the following prompts so I can learn how to best support you as a learner.

1. What has been your experience learning science? Describe the activities that have facilitated your learning.
2. What are your current beliefs toward science? How do you feel about learning science? Why do you feel this way?
3. Do you enjoy learning science? Explain why or why not.
4. Do you see connections/applications with science outside the classroom? Explain why or why not.
5. In elementary school, were you able to apply what you learned in your science classes to your everyday life?
6. Do you see yourself as a science person? Explain why or why not.
7. Describe the qualities of effective teachers who teach science. What qualities benefit students in learning science?

Revised Science Teaching and Learning Autobiography

Take a moment to review your original responses to the Science Autobiography assignment, particularly Section 2, submitted at the beginning of the semester. Now that we have had an opportunity to study more about elementary school science and ways to teach science in elementary settings, please respond to the following prompts. Use your responses in Section 2 to reflect on changes in your beliefs and attitudes toward teaching and learning science.

1. What are your current beliefs toward science? How do you feel about learning science? Why do you feel this way?
2. Do you enjoy learning science? Explain why or why not.
3. Do you see connections/applications with science outside the classroom? Explain why or why not.
4. Do you see yourself as a science person? Explain why or why not.

Appendix B

Convergence of Quantitative and Qualitative Data

Domains	Quantitative Findings		Qualitative Themes	Mixed Methods Meta-Inferences
	Variables	Change in Mean (T1 - T2)	Representative quotes from post-Science Autobiography (A2)	
Science Teaching	*Teaching Outcome Expectancy* PSTs' perceptions of a teacher's role as impacting students' science knowledge	3.63 - 3.91 ↑ 0.28	*Positive Beliefs* I feel like learning science does not have to be a negative thing or straight from the textbook, like how I used to think, because that was always the way I grew up learning science for the most part. I feel like it can be made fun if there is a teacher who is willing to put in the effort. (PST 7, A2) I am beginning to see myself more as a science person and a science teacher. After learning multiple strategies for how to teach science, I feel more confident with science content and being able to teach it to students; therefore, I think that my view of myself as a science person is continuing to grow as I am exploring more with students and expanding my knowledge of science, while also seeing the potential within the subject. (PST 26, A2) *Interest in Science Teaching* I still agree with what I said at the beginning of the semester, but now I feel more excited and more confident in myself to teach it. This semester I taught my first science lesson and it went really well. (PST 8, A2)	*Confirmation* Participants alluded to learned pedagogy, increased content knowledge, and a mastery experience throughout the semester as the reasons for increased teaching self-efficacy, aligning with the STEBI quantitative measure.
	Teaching Efficacy PSTs' beliefs about their ability to teach science	3.56 - 4.01 ↑ 0.45	*Interest in Science Teaching* The idea of teaching science kind of freaked me out because I still didn't understand it so I didn't think I would be able to even teach it. Now, every time I learn something new from this course, I get so excited because I get it. It's no longer a foreign concept nor is it teacher-driven where I was expected to memorize facts and somehow apply critical thinking on worksheets. I quite enjoy it. (PST 11, A2)	*Confirmation* Participants elaborated on increased teaching efficacy due to learner-centered lessons participated in during the course which aligns with associated STEBI subscale findings.
	Science Efficacy PSTs' beliefs about	3.13 - 3.97 ↑ 0.84	*Understanding of the Nature of Science* I have been through a whirlwind of emotions this semester regarding my beliefs and confidence towards science and teaching science. Things	*Confirmation* Participants describe a

	their ability to complete college science courses	definitely got worse before they got better, as when I learned and compared myself I was able to see the holes in my knowledge. However, now I feel more confident. Not in my current knowledge, but in my ability to learn about science. I trust that I have more tools in order to help me answer my own questions and curiosities. (PST 55, A2) At the beginning of the semester, no I did not see myself as a science person. Now, here at the end of the semester. I can honestly say that I see myself as a science person. Now I'm able to obtain, evaluate, and communicate information that I once was afraid to do because I didn't know how to explain the way I was thinking when it came to science. (PST 8, A2)	perceived increase in their ability to ask questions and communicate findings to engage in science, which confirms the STEBI subscale results.
Science Learning		*Positive Beliefs* I originally didn't see myself as a science person at the beginning of the semester. However, this has definitely changed throughout the course of the semester. I now have a new enjoyment when it comes to learning about science…. I have learned so many ways to make science enjoyable for myself and my future students. (PST 20, A2)	
		Negative Beliefs I do not see myself as a science person. I say this only because I do not feel like it is my strongest subject to teach or learn about on my own. During class discussions, my peers would say something or make a connection that I would have never even thought of or been able to answer, but it gave me a lot of insight into the topic that we would be discussing. I do not think I will ever see myself as a science "person." However, I can see myself as a good science teacher for my students.	*Divergence* Participants noted not seeing themselves as a science person due to content knowledge. The quotes illustrate a difference in the overall STEBI results from this subscale.

Note. PST = Preservice Teachers, T1 = Time 1, T2 = Time 2, A2 = Science Autobiography at Time 2

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Please Cite: Nafziger, B., Moldavan, A. M., & Brady, A. C. (2026). Examining growth in preservice science teaching and learning self-efficacy using mixed methods. *Journal of Research in Science, Mathematics and Technology Education, 9*(1), 23–43. DOI: https://doi.org/10.31756/jrsmte.912

Conflict of Interest: The authors declare that there is no conflict of interest related to this work.

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Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement: This study was conducted in accordance with ethical standards for research involving human participants. All procedures were reviewed and approved by the appropriate institutional ethics committee, and informed consent was obtained from all participants prior to data collection.

Author Contributions: All authors contributed equally to the conception, design, data collection, analysis, and writing of this manuscript.

Received: June 29, 2025 ▪ Accepted: November 28, 2025