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Investigating Preservice Teachers' Science Teaching Self-Efficacy: an Analysis of Reflective Practices

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Abstract
The purpose of this mixed methods research was to investigate the development of 55 preservice elementary teachers' science teaching self-efficacy beliefs through analysis of their reflective practices in a science method course. This year-long study was conducted at two public universities located in the USA and Canada. Within the theoretical frameworks of science teaching self-efficacy and reflective practice, we examined how and in what ways preservice teachers' reflections on their past science experiences and current science teaching practices contributed to their self-efficacy beliefs. Data were collected from pre- and post-course administrations of the Science Teaching Efficacy Belief Instrument-B (STEBI-B), written science autobiographies, written reflection papers, classroom observations, and artifacts.

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A repeated-measures analysis of variance (ANOVA) was used to test the significance of the differences between the pre- and post-course survey scores. The results indicated statistically significant gains in participants' science teaching self-efficacy beliefs. The qualitative analysis revealed that preservice teachers' initial self-efficacy beliefs evolved through years of formal and informal interactions with science. New levels of self-efficacy were reached, as evident from participants' self-reflection on their field teaching. The findings indicate the importance of field experiences and reflective practices for preservice elementary teachers' preparation and science teaching self-efficacy. The study offers implications for preservice teacher education programs, science teacher education, and research.

Keywords: Preservice teacher education . Science teaching self-efficacy . Reflective practice

Introduction

Science education reforms across the globe emphasize high-quality science teaching in elementary classrooms (Australian Curriculum, 2015; Newfoundland and Labrador, Department of Education, 2015; Next Generation Science Standards [NGSS], 2013). Unfortunately, elementary teachers lack confidence in science teaching (Abell, 2007; Appleton, 1995; Darling-Hammond, 2000; Taylor& Corrigan, 2005). A recent survey of elementary teachers in the USA and Canada suggested that few teachers (33%) feel prepared to teach science (Banilower et al., 2013; Rowell & Ebbers, 2004; Trygstad, Smith, Banilower & Nelson, 2013). A lack of a positive connection and personal involvement with science interferes with science teaching self-efficacy beliefs, and thus, many elementary teachers avoid teaching science altogether (Avery & Meyer, 2012). In the field of science education, higher levels of science teaching self-efficacy are critical for long-term success (Bandura, 1982; Mulholland & Wallace, 2001) and retention in the field (Aldridge & Fraser, 2016; Yost, 2006). Broadly, teacher self-efficacy refers to a teacher's sense of *competency*, which implies beliefs in one's capabilities to make decisions and perform actions that could lead to positive student outcomes (Bandura, 1977). Literature posits that K-12 experiences as well as teacher preparation coursework play a vital role in shaping preservice teachers' self-efficacy (Avery & Meyer, 2012; Bautista, 2011; Menon & Sadler, 2016, 2018).

Research on preservice teacher education have identified a variety of factors within teacher preparation courses that influence the development of preservice elementary teachers' self-efficacy including instructor modeling of instructional approaches, such as watching video footage of exemplary teachers using the learning cycle (Narayan & Lamp, 2010; Rice & Roychoudhury, 2003; Settlage, 2000; Yoon et al., 2006), hands-on inquiry investigations (Gunning & Mensah, 2011; Mulholland & Wallace, 2001), and lesson planning and field teaching (Hancock & Gallard, 2004; Leonard, Barnes- Johnson, Dantley & Kimber, 2011; Palmer, 2006). Studies suggest that science teaching self-efficacy is highly influenced by the experiences preservice teachers gain within science method courses and student teaching practicum (Bautista, 2011; Gunning & Mensah, 2011; Palmer, 2006). Reflection is a widely used practice in preservice teacher education that allows preservice teachers to write reflections on their classroom teaching (Amobi, 2005; Davis, 2006). Amobi defined reflective practice as "a tendency to revisit the sequence of one's teaching for the purpose of making thoughtful judgement" (2005, p. 116). More recently, the conceptualization of reflective practice has been expanded from its traditional view of merely having preservice teachers follow a series of steps to analyze their teaching and write reflections. Critical reflection allows preservice teachers to examine their past experiences that may have shaped their ideas and beliefs about science teaching and learning (Amobi, 2005; Hatton & Smith, 1995). This type of detailed analysis will take into account that preservice teachers confront and interpret their science teaching beliefs in light of their current teaching practices for future improvement and reach new levels of confidence in science teaching (Yuan & Mak, 2018).

While the benefits of reflective practices in preservice teacher preparation programs have been widely accepted in the literature (Bautista, 2011; Brand & Wilkins, 2007), little is known about how and in what ways preservice elementary teachers' written reflections provides information about their development of self-efficacy beliefs. Prior studies suggest positive links between teacher's reflective thinking on teaching experience and future teaching practices, and more studies are needed to examine these critical links (Soprano & Yang, 2013, Wang & Lin, 2008). Unlike prior studies on preservice teacher self-efficacy in which written reflections (on field-teaching) have been used as stand-alone tasks or assignments after field teaching, this study builds on the viewpoint that reflective thinking is an ongoing process that provides unique and personal insight into the thoughts, beliefs, feelings, concerns, and, ultimately, the potential strategizing of preservice teachers.

Preservice teachers enter their science methods coursework with a set of beliefs about science and science teaching originating from their K-12 science learning experiences (Bautista, 2011; Mulholland & Wallace, 2001). Researchers in the field suggest that self-reflection allows a person to "think about the self" contributing to one's understanding "to regulate personal behavior, which further impacts confidence in one's ability to perform in a specific area" (Bandura, 1986; Jensen, Huber, Cundick & Carlson, 1991, p. 525). However, what is unclear is that how preservice teachers' reflective thinking could potentially be used understand the development of science teaching self-efficacy, given the opportunity to think about their science teaching and learning experiences. For science educators, the critical question is what aspects of their science methods course and field experiences do preservice teachers choose to reflect on and write about, and how are these reflections suggest development in their science teaching self-efficacy. The study will shed light on the use of self-reflection as a means to gain insights into preservice teachers' self-efficacy by in-depth analysis of preservice teachers' reflections on their life and science teaching and learning experiences. Thus, the study attempts to take a closer look at preservice elementary teachers (PETs)' changes in self-efficacy as they engage in self-reflection of their past science learning experiences and current teaching practices.

The following research questions guide this investigation:

(1) What factors associated with prior science experiences do PETs emphasize in their self-reflection at the beginning of a science methods course?

(2) How do PETs' science teaching self-efficacy beliefs change at the end of the science methods course and what aspects of the field experiences (as highlighted in the reflections on teaching) contribute towards this change?

Theoretical Framework and Background Literature

This study draws on two theoretical underpinnings: (1) science teaching self-efficacy and (2) reflective practices in teacher education.

Science Teaching Self-Efficacy

Self-efficacy, derived from social cognitive theory, is an important construct that influences teachers' decision-making and teaching practices (Bandura, 1977; Watters & Ginns, 2000). Bandura (1977, 1982) conceptualized self-efficacy as "a person's estimate that a given behavior will lead to certain outcomes" (p. 79). Based primarily on Bandura's work, Ashton and Webb (1982) identified that the two dimensions, namely, teaching efficacy and personal efficacy, account for individual teacher differences in performing actions and decision-making. Gibson and Dembo (1984) applied both Bandura's and Ashton and Webb's theory to develop the questionnaire called Teacher Efficacy Scale and their analysis of 208 elementary teachers' responses on the questionnaire confirmed two-dimensionality of self-efficacy. Based on Bandura's work, Riggs and Enochs (1990) proposed that self-efficacy beliefs can be teased out into two separate, yet related, dimensions: personal science teaching efficacy (PSTE) beliefs relate to an individual's ability to execute actions required to achieve desired goals and science teaching outcome expectancy (STOE) relates to individuals' judgments of the anticipated results that their performances may produce. Consistent with Bandura, Guskey and Passaro (1994) suggested that the two dimensions of teacher self-efficacy are related but yet independent of each other.

This research adopts Bandura's conceptualization of self-efficacy suggesting that personal beliefs may influence learning and motivation that ultimately affects outcomes in terms of the effort future teachers may put forth with regard to their own teaching. Given that higher levels of self-efficacy influence teacher behavior, decision-making, and practices, close attention to preservice teachers' self-efficacy beliefs is warranted. Studies have reported that science methods courses and field teaching are successful in enhancing preservice teachers' self-efficacy, as they provide rich sources for the development of self-efficacy (Avery & Meyer, 2012; Brand & Wilkins, 2007; Gunning & Mensah, 2011; Rice & Roychoudhury, 2003).

Reflective Practice

For more than two decades, researchers have conceptualized and defined reflective practice in teacher education in many ways. Earlier conceptualizations of reflection include Schon's (1982) description of "reflection-in-action" as a process that leads to better performance or action. Schon's notion of reflective practice suggesting a "dichotomy of thought and action" (p. 280) gained tremendous attention among teacher educators. Dewey (1933) proposed that reflective thought involves "a sequence of ideas" and "a consequence" (p. 68) guided by the process of experimentation and reflection to aim for better education and student learning. Other viewpoints on reflective practice directed at practitioners include reflection-on-action, which refers to "a tendency to revisit the sequence of one's teaching for the purpose of making thoughtful judgement" (Amobi, 2005, p. 116).

In preservice teacher preparation programs, reflecting on practice teaching is widely used as an instructional tool by teacher educators. Reflective practice has been identified as a process of self-reflection that helps teachers interpret, analyze, and reflect on their life experiences, current beliefs and classroom practices (Yuan & Mak, 2018). Several researchers have investigated how engagement in reflective practice helps preservice teachers develop their reflective thinking skills. For example, in a study conducted by Wang and Lin (2008), preservice teachers' reflections suggested improvements in their conceptions of inquiry teaching at the end of the science methods course. Similar results were found from the study conducted by Soprano and Yang (2013), where preservice teachers' reflections and self-efficacy score an increase in understanding of inquiry-based science teaching and learning after their field experiences.

Literature suggests various strategies for fostering preservice teachers' reflective practice including written reflections on clinical experiences, action research projects, video-based reflection assignments, journal writing, portfolios, and weblogs (Davis, 2006; Hawkins & Park Rogers, 2016; Kleinknecht & Schneider, 2013; Lee, 2005; Yuan & Mak, 2018). In addition, a variety of models, criteria, procedures, and rubrics related to preservice teachers' reflections are available, but they are often inconsistent. Furthermore, the focus of reflections can vary widely because of the variety the issues and concerns individual preservice teachers confront in student teaching. As a result, there is a lack of consensus in the literature on the conceptualizing reflection, given that a variety of typologies exists in the literature to capture its complexity (Jay & Johnson, 2002; Lee, 2005). The lack of consensus in the literature adds to the concern and confusion among teacher educators about ways to assess preservice teachers' reflections in their programs. Furthermore, how and in what ways reflective thinking provides insights into the development of science teaching self-efficacy has yet to be explored. This study will address this gap by investigating PETs' use of reflective practices to understand how self-efficacy is shaped as PETs gain new experiences in science methods and field teaching.

Methodology

Research Design

This mixed method study utilized a triangulation convergent design (Creswell & Plano Clark, 2007). A mixed methods approach avoids any potential biases of using a single method in investigating a complex phenomenon (Denscombe, 2008; Morse & Niehaus, 2009). In this mixed-methods research, triangulation was used for convergence, corroboration, and correspondence of results from quantitative and qualitative methods (Greene, 2007). We intended to converge and corroborate findings from quantitative and qualitative data analysis to reveal that qualitative analysis from the science autobiographies and written reflections corroborates quantitative analysis that suggests the changes in PETs' science self-efficacy. The triangulation increased rigor through its demonstration of the convergence of results from multiple methods, theoretical frames, and value perspectives (Cook, 1985). While quantitative analysis targeted to explore the changes in PET's science teaching self-efficacy on the two scales (PSTE and STOE), qualitative analysis of their written reflections intended to illuminate the factors that affect the changes in self-efficacy after their exposure to the science methods course and field experiences. In the "Discussion" section, we have converged, compared, and synthesized both quantitative and qualitative findings to discuss the positive gains in participants' science teaching self-efficacy.

Research Context

This study was conducted at two research sites: (1) a large mid-Atlantic university in the USA and (2) a Canadian public university in the Atlantic region. While both countries strongly promote inquiry-based teaching and learning as advocated by the various calls for reforms, there are subtle differences in their vision, nature, and government standards, which ultimately shaped the approaches to science teaching that are employed within science education courses at the two institutions. Despite the subtle differences between the positionalities of students at the US and Canadian institutions, there are similarities given the shared North American context (language, ethnicity, and broader Western culture), which strengthened the validity and generalizability of the two groups. Even though there are similarities between the two cultures in a broader sense, we contend that there are individual differences across the two groups (the U.S. and Canada), considering the differences between life experiences, K- 12 science learning experiences, and communities in which individuals participate in, learn, and grow (Avraamidou, 2019). In addition, we also contend that factors such as individual participant's belief system, values, classroom interactions within the science methods course and elementary school during student-teaching, and individual science methods course instructor's modeling and teaching style may contribute towards subtle differences in the two courses at the two institutions (Kier & Lee, 2017; Menon, 2020).

The study was conducted with two course sections in the Fall 2017 semester and one course section in the Spring 2017 semester. Both course instructors, researcher 1 (USA) and researcher 2 (Canada), met each week during the summer semester prior to the semester during which the study took place to plan and design the science methods course and maintain the same scope and sequence. The total credit hours, structural elements, and content were the same for both the USA and Canada classes; the only difference was the frequency and duration of the class at each institution. At the US site, the class met for approximately 3 hours and 50 min once a week for 15 weeks. Each course section usually enrolls approximately 15–18 early childhood and elementary majors. At the Canadian university, the class met twice a week for approximately 2 hours and 20 min for 12 weeks. The enrollment in the course typically ranges from 20 to 25 PETs.

The course aimed to develop PETs' knowledge and skills necessary to facilitate science lessons that utilize inquiry and science and engineering practices, for example, forces affecting flight were discussed through a simple activity of making paper airplanes, formulating and investigating questions about paper airplanes, testing the flight of the paper airplanes, and improving the design of the paper airplanes using the design process. Working in groups of 4–5, preservice teachers designed 3–4 science lessons (a mini-unit) based on the science topics covered and the pedagogical approaches discussed and enacted these lessons individually in an elementary classroom (field experience). The practice teaching lasted for approximately 40–45 min at least four times a semester in which each participant taught the lesson to a small group of students (5–6 students per participant). Another distinctive component of the course was engaging preservice teachers in reflective practice with an aim to develop their reflective thinking skills to emerge as "reflective practitioners" (Yuan & Mak, 2018). Reflections were not restricted to the analysis of classroom teaching but also includes reflection on life histories and past experiences with science. **Table 1** details the course components, a description of the activities and assignments and the intended sources of science teaching self-efficacy these components provide.

Participants

A total of 55 participants volunteered to participate in the study. At research site 1 (USA), of the 42 PETs enrolled in the course during the Fall and Spring semesters, 36 volunteered to participate in the study. Most of the participants were enrolled in their junior year, except for three, who were in their senior year. There were 35 females and one male, and all participants ranged in age from 20 to 23, with a few exceptions (three participants aged 25 and one participant aged 33 years). A majority of the participants were Caucasian except for 4 Asian, 7 Hispanic, 1 Ethiopian, and 1 Native American participant. At research site 2 (Canada), a total of 27 PETs enrolled in the class in the Spring 2017 semester, and 19 volunteered to participate in the study. There were 18 females and one male participant, all between the ages of 20 and 25, except one participant who was 30 years old. All participants were of white Canadian ethnicity.

Table 1 Science methods course assignments and activities

Course components	A detailed description of the activities/ assignments	Potential sources of science teaching self-efficacy
Hands-on scientific investigations	In small groups (3–4), preservice teachers participate as learners to conduct simple hands-on science investigations.	Learning via social interactions involves the exchange of ideas leading to an increase in confidence in the science content specific to elementary science teaching.
Science and Engineering practices/ inquiry-based pedagogical approaches	Science and engineering practices (outlined in the NGSS) are embedded within each science lesson using a 5E model. There are explicit discussions on and about each stage of the 5E model as well as the practices	Increase in pedagogical content knowledge as a result of engaging in a specific content/topic using reform-based teaching practices and 5E learning cycle
Collaborative lesson planning	Preservice teachers work in collaborative teams (3–4 per group) to plan and design a practice-based science lesson for elementary classrooms	Opportunities to brainstorm ideas, negotiating roles, building relationships, and increased in the sense of belonging within the “community of teacher-learners”
Field-based teaching in a formal classroom setting	Each preservice teacher teaches the science lesson in a local elementary school classroom to a small group of students (5–6) for 40 min. They also engage in discussions about their lesson with mentor teachers, peers, and course instructor (debrief sessions)	Increase in confidence in science teaching through first-hand teaching experience. Social interactions with young learners contribute towards their teacher’s sense of self that allows them to bridge the gap between theory and practice and establish a foundation to exhibit praxis
Reflective practices	Preservice teachers write a science autobiography (reflective narrative of prior science experiences), and reflect on their classroom teaching (reflections-on-action)	Increased ability to reflect critically on the life experiences, events, situations, and classroom episodes that contribute towards beliefs about science and science teaching

Data Collection

Data were collected in three distinct phases. During the first phase, which occurred at the beginning of the semester, the quantitative data sources included demographic and open-ended questionnaires and the STEBI-B as a pretest. The qualitative data sources included participants' written science autobiographies. During the second phase, the qualitative data sources included teaching observations, researchers' field notes on student-teaching sessions, lesson plans, artifacts, and individual reflection papers. The third phase of data collection included the post-course administration of the STEBI-B and an open-ended questionnaire.

Description of the Quantitative Data Sources

STEBI-b. The revised version of the STEBI-B (originally developed by Enochs and Riggs (1990)) was used in this study as a pretest and a posttest (Bleicher (2004). The STEBI-B consists of 23 items (13 items in Personal Science Teaching Efficacy scale (PSTE) and 10 items in Science Teaching Outcome Expectancy (STOE) scale) with a 5-point Likert scale that ranges from 1 (strongly agree) to 5 (strongly disagree). The PSTE subscale scores range between 13 and 65, and the STOE scores range from 10 to 50. Higher scores represent higher self-efficacy beliefs. The reliability of the STEBI-B for this sample was calculated using Cronbach's alpha. The Cronbach's alpha values indicating the internal consistency of the PSTE subscale of the pre- and posttests were 0.83 and 0.86, respectively. The reliability coefficients for the STOE subscale of the pre- and posttests were 0.66 and 0.70, respectively. These values are well above the accepted lower limit of 0.65 (Chandrasegaran, Treagust & Mocerino, 2007). We contend that the low Cronbach's alpha value for the STOE subscale on the pretest might be due to relatively less developed views on outcome expectancy as students had not completed their field experiences.

A demographic survey and an open-ended questionnaire were administered on the same day as the administration of the STEBI-B. The open-ended questions were centered on participants' motivation to become science teachers and the associated factors from their past science experiences.

Description of the Qualitative Data Sources

Written Science Autobiographies

Written science autobiographies were well suited to the purposes of this study as one of the primary sources of data because the participants' stories provided information regarding previous experiences and how they had influenced the participants' current beliefs about science and science teaching. For example, one of the prompts asked participants to summarize their experiences from the high school science course they enjoyed the most and to describe specific things within the course that were enjoyable. The participants were encouraged to share incidents and events that occurred in formal or informal settings that they believed to be "critical" in shaping their views (positive or negative) of science and their decisions to pursue teaching as a profession. These autobiographies were collected online within a week of the start of the course to avoid any influence of the science methods course experiences on their present beliefs about science teaching.

Reflections on Teaching Practice

Based on the notion of reflective practice as focusing on one's teaching to "see what matters in a classroom" (Davis, 2006, p. 281), PETs' written reflections also served as a primary source of data. In this study, the purpose of engaging preservice teachers in writing reflection papers was to allow them to (1) reflect on science methods course aspects (see **Table 2**) that helped them develop their knowledge and understanding of methods of science teaching, (2) select teaching episodes, and critically analyze them to make judgments about the strengths and weaknesses of their own teaching and to suggest ways to improve their science lessons for future science teaching. Each participant wrote individual reflections after each teaching session in an elementary classroom, for a total of 3–4 reflections per preservice teacher.

In addition to the primary data sources described above, secondary data sources included the instructors' observations of student-teaching sessions and field notes and artifacts such as science lesson plans. The in-class observations focused mainly on observing and taking detailed notes on preservice teacher-student interactions.

Table 2 Sample Coding Scheme for Science Autobiographies and Reflections

Category (description)	*Codes*	*Sample excerpts*
Science autobiographies		
Learner effect (prior science learning experiences and its impact on one's initial beliefs about science)	(Positive) Fun and excitement, enjoyed the science class. (Negative) Stressful chore	"The positive experiences that I had in my high school science classes impacted my beliefs about science by pushing me to want to learn science and be excited about science" (Participant 2).
Teacher effect (personal connections with prior science teachers and its impact on one's interest in science)	Caring and enthusiastic (positive), did not care, not approachable (negative)	"The teacher had a huge part in my motivation, she was not very nice to me, and I felt ignored" (Participant 3).
Relevance of the content (real-life connection with science)	Real-life examples, seeing the process in a real-life setting	"I only liked the physics portion of the course because I found it interesting that a lot of real-life examples" (Participant 3).
Pedagogical strategies used by prior science teachers	Experiments, worksheets, more lecture	"My teacher had us do more experiments than just worksheets, and that made the classroom fun" (Participant 4).
Family and informal learning experiences	Family member as an inspiration for science, field trips, excursions	"One person who inspired me to enjoy science is my father. He loves to learn how things work and he is the reason I like it so much" (Participant 16).
Reflections		
Engaging young learners in science (elementary students engagement in science activities to facilitate conceptual understanding)	Prior student conceptions, student participation, student learning, excitement, engaged	"We attempted to engage the students while also gauging their prior knowledge about speed, gravity, work, and friction. We did this through a discussion and asking students" (Participant 10)
Pedagogical strategies to enhance student-centered instruction	5E model encourage higher-level thinking, hands-on activities	5E model helped us ensure of an effective lesson to encourage higher-level thinking (Participant 2)
Teacher attributes to support student learning	Planning and organization, preparing materials	We had all of our supplies ready to go throughout the process to ensure that there were limited distractions and waiting… (Participant 7)
Assessment strategies to assess student learning	Guiding questions, more preparedness in assessments	I felt much more prepared to ask guiding questions during this lesson than I had in the past (Participant 12).
Challenges associated with classroom teaching	Classroom management, responding to student questions	I can honestly say I could have been more prepared for the student's statements and questions" (Participant 1)

Data Analysis

Data analysis proceeded in two distinct phases, including (1) a quantitative phase and (2) a qualitative phase. Below, we describe each of the two phases.

Quantitative Data Analysis

The pre-post STEBI-B responses were analyzed using the IBM Statistical Package of Social Science (SPSS) software (Version 21.0 for Windows 8). Pre-post repeated measure analysis of variance (ANOVA) was used to determine the significant differences between the pre- and posttest mean scores. The F statistics calculated from Wilks's lambda were used to test the significant differences in the mean scores over time. The null hypothesis was that there were no significant differences in the mean science teaching self-efficacy scores between the pre- to posttest. Univariate tests were conducted, and time was used as the within-subjects factor to determine the changes in science teaching efficacy from the pre- to posttest. Partial eta squared (η^2) values were used to estimate the effect size.

Qualitative Data Analysis

Analysis of the science autobiographies and reflection papers proceeded in two distinct phases. First, the data were analyzed using open coding that involved reading the raw data for common factors or events as described by the participants. After the data were read and reread multiple times, the initial codes were assigned. When analyzing the excerpts from science autobiographies, we looked for words or phrases used by preservice teachers to express their views and perceptions about science by narrating episodes from past science experiences as well as expressions about their present views about science. In this sense, we particularly paid attention to cues that provided a sense of continuity throughout their past K-12 science experiences and their present positioning as a teacher of science. The two researchers (the first and second author) independently coded two autobiographies that were randomly selected. After the initial discussion, both researchers coded four additional autobiographies.

The interrater agreement, using Cohen's kappa, for the first round of analysis (based on 10% of the data, i.e., six autobiographies) was found to be 0.710, which indicated slightly low agreement between the two researchers according to Cohen's guidelines (Hallgren, 2012). After the discussion, until a consensus was reached, six additional autobiographies were coded. Cohen's kappa value was found to be 0.921, indicating strong agreement between the two researchers (Hallgren, 2012).

In the second phase, axial coding was employed, and the researchers created a coding scheme to organize the major categories and the codes within each category, describe the categories, and select excerpts from the data. Similar process was carried out for analyzing reflection papers. When analyzing the excerpts from written reflections, we looked for words, phrases, and descriptions around the aspects of teaching that preservice teachers highlighted from their classroom teaching. We paid close attention to look for *connections* between the experiences of working in a classroom and the expressions of professional growth as a future teacher to establish a continuum between their present experiences and future teacher self. All qualitative data were coded according to the established coding scheme (see Table 2). The themes and categories were triangulated across multiple data sources. Peer debriefing and triangulation across multiple data sources were utilized to establish trustworthiness. The secondary data sources, such as observations and artifacts, were used for corroborating research findings.

Findings

In this section, we first present the findings for the research question 1 organized under five categories, representing factors associated with PETs past science experiences that they referenced in their science autobiographies. Then, we present the findings for the research question 2 framed under quantitative (STEBI-B analysis) and qualitative themes from the written reflections.

Impact of Prior Science Experiences

Five major categories emerged: (1) learner effect, (2) teacher effect, (3) relevance of the content, (4) pedagogical strategies used by teachers, and (5) family/informal learning experiences.

Learner Effect

Under this category, we discuss how participants describe their prior experiences as learners of science in their K-12 and college science classes, which seemed to have an impact on their present beliefs about science teaching. About 65% of participants indicated a strong affinity for science and their explanations suggested either their personal interest in science or fun in the process of learning science. For example, one participant mentioned, "I enjoyed science as being able to explore and discover new things in a fun, creative way" (Participant 4). Another participant wrote that "solving the *mystery* aspect in science is interesting and getting to learn about what was out there and how much we still have to learn" (Participant 5).

Conversely, 35% of the participants expressed discomfort with learning science with most of the explanations relating to experiencing failure of some sort leading to stress and anxiety while learning science. For instance, one participant expressed her frustration: "It wasn't a process that I received a lot of help with at school, so I really felt alone in that regard. It wasn't fun, it was a stressful chore" (Participant 10). Interestingly, a majority of participants who shared negative experiences also suggested meaningful insights related to things that they did not want to repeat with their own future students when teaching science. For instance, one participant wrote, "I think the negative experience with science has shaped me to try and not to become the teacher that I did not enjoy having. I would want to show students how much fun science could be. I want to make my students not to feel the way that my past teachers have made me feel" (Participant 4).

Teacher Effect

In this category, participants described their personal connections with prior science teachers as well as explained how these connections influenced their interest in the topic. In general, most participants (71%) felt motivated when their science teachers were enthusiastic and showed genuine interest in student learning, and accordingly, 29% felt demotivated when their teachers were not approachable or less caring. As participant 11 quoted:

> The teacher had a huge part in my motivation, she was not very nice to me, and I felt ignored. I honestly felt as if she did not care if I was in class trying or not. So, I thought if my own teacher does not care, why should I care about this anatomy class? I feel that the lack of my teacher's interests towards me opened doors for my interests to decrease.

It appeared that the classroom discourse and interactions with science teachers influenced participants' affinity towards science. For example, one participant shared, "The great teachers I had made me believe I was smart enough to learn the things they were teaching and actually enjoy a subject I used to hate" (Participant 6).

Relevance of the Content

A vast majority of participants (84%) found that certain science topics that were relevant to the real world were more interesting to them than the others. For instance, Participant 3 said, "I only liked the physics portion of the course because I found it interesting that a lot of real-life examples were used to help explain the concept of physics." The topics that allowed participants to explore or observe the real world instead of learning from the book were more relatable to them. For instance, a participant expressed: "I really enjoyed biology unit because we weren't just reading about the lifecycle in a book, we were actually observing it on a day-to-day basis and seeing this process in a real-life setting. I also loved animals, so I enjoyed learning about farm animals and different species." On the other hand, 16% of participants felt either overwhelmed or bored on topics that were abstract in nature or difficult to comprehend. As Participant 6 noted, “The class I struggled in the most was physics. I could not get the concepts most of the time, and it didn’t make sense to me.”

Pedagogical Strategies Used by Prior Science Teachers

Most participants (96%) referred to the pedagogical strategies their teachers used and how these strategies reinforced or hindered their learning. They appreciated the hands-on experiments as oppose to traditional methods; as one participant said, “My teacher had us do more experiments than just worksheets, and that made the classroom comfortable and fun” (Participant 4). Others shared that their teachers used traditional methods, which they did not find appealing. For instance, Participant 12 explained, “Biology was not my favorite because we had minimal experiments. It was more of a lecture course than anything else. The educator did not allow us to complete experiments or labs, so I felt like I did not learn as much.” Based on their experiences, many participants seemed to develop views about ways in which science should be taught to young learners, as one participant shared, “I feel children learn best when given the opportunity to experience it for themselves. I learn best by doing things myself and seeing the product visually” (Participant 2).

Family and Informal Learning Experiences

Approximately 71% of the participants described informal experiences from their early lives that served as a driving force for their interest in science; the other 29% did not discuss any informal learning experiences. The examples included excursions; family trips to forests or geographical sites; and school science fair projects or field trips. Some participants described their family members, parents, or siblings as an influential person. For example, Participant 16 noted, “One person who inspired me to enjoy science is my father. He loves to learn how things work and he is the reason I like it so much.” We noticed, not surprisingly though, that only a few participants (8%) described their views about the benefits of informal learning experiences in science education. For example, “It is important to explore the world around us, as it is about unpacking ideas and concepts that seem complex. This can include field trips or interactive outdoor education” (Participant 12).

Development of Science Teaching Self-Efficacy

In this section, we provide quantitative evidence of the changes in participants’ science teaching self-efficacy (STEBI-B results). Then, we describe the results from the analysis of written reflections under five categories.

Quantitative Findings

Multivariate tests showed significant differences in the mean STEBI-B subscale scores over time [$\Lambda = .477$, $F\ (2, 53) = 29.045$, $p < 0.001$, $\eta^2 = .523$]. Univariate tests (repeated measures ANOVA) showed a significant increase in both the PSTE ($F\ (54) = 48.777$, $p < 0.001$) and STOE ($F\ (54) = 12.583$, $p<0.001$) mean scores. The mean PSTE score significantly increased from pretest ($M= 48.111$, $SD = 7.057$) to posttest ($M= 54.730$, $SD = 6.279$). The mean STOE score significantly increased from pretest ($M= 35.560$, $SD = 3.881$) to posttest ($M= 37.780$, $SD = 3.478$). The partial η^2 values, which indicate the practical significance of the effects, were higher for PSTE than STOE, explaining that 47.5% of the variance was explained by PSTE. One logical explanation for the moderate effect on STOE is that many participants encountered research-based practices in science learning and teaching for the first time.

Qualitative Findings

Under the description for each of the five categories below, we discuss examples shared by preservice teachers in their written reflections representing aspect of the science methods course and field experiences contributing to the development of science teaching self-efficacy.

Engaging Young Learners in Science

A majority of participants (80%) associated success in science teaching with ways in which they engaged young learners in classrooms and giving opportunities for students to become active learners. One participant shared the "engage" phase of her lesson on energy where she designed a game to gather student's prior knowledge about energy, "We played the game, and I was very impressed with how thoughtful and thorough the students were…this made me feel confident, and I was actually surprised that the students were able to tell ways that we get energy" (Participant 4). Not only participants shared their success stories of greater student involvement in their lessons, many shared ideas to help their future students become independent thinkers while providing more opportunities to involve them with the activity. Below, we provide an example from the lesson on energy using ramp and ball investigation where students conduct simple investigations on how far the ball would go with increasing the ramp-height. In the example here, the participant is sharing ways to increase student involvement by doing the activity in a small group rather than a whole-class activity:

> Students predicted and ran two trials to see how far the ball would roll. I would have liked to do this in small groups instead of a large group to ensure each student understood the concept. I think this is important, as I want each child to have the opportunity to drop the ball. Each child will be able to use the first-hand experience to see the relationship between height and distance the ball moved. (Participant 3)

Notably, this participant acknowledged the importance of engaging *all* learners in the activity and had insights on how to provide rich and engaging experiences in her future teaching. Also, the participant is thinking in terms of the *outcome* she desires when referring to the *action* "having each child drop the ball" and the anticipated outcome of the action that each child will be able to understand the relationship between height and distance.

About 20% participants referred to their science methods course that engaged them in hands-on science experiments in a similar way as learners as they were expected to teach in their classroom. For example, one participant expressed, "Through participating in experiments using different forms of inquiry, my classmates and I were better able to appreciate the value of integrating them into our own future classroom. I now understand the value of introducing a variety of inquiry experiences in the classroom" (Participant 5). What we also noticed is that many participants reflected on how they were conscious of the strategies they chose in their lessons to ensure multiple means of engagement and maximize student participation. As one participant mentioned, "We attempted to engage the students while also gauging their prior knowledge about speed, gravity, work, and friction. We did this through a discussion and asking students to imagine themselves riding a bike. We asked what would happen if they encountered a steep hill, a patch of ice, strong winds, and other scenarios" (Participant 10).

Pedagogical Strategies to Enhance Student-Centered Instruction

Another aspect related to field teaching that participants mentioned in their written reflection was on pedagogical strategies and its importance on helping students learn scientific concepts. Science methods course introduced participants to the 5E model and inquiry approach, and many referred to how their understanding of 5E translated well in their lesson implementations. About 51% of participants acknowledged that "there are many different ways to approach [a science] concept," and they intentionally designed "lessons to be student-centered and as interactive as possible to convey the ideas" (Participant 3). One participant described that the "5E model helped us ensure that we included all of the necessary components of an effective lesson to encourage higher-level thinking and to ensure we had as much engagement as possible" (Participant 2). Participants noted that the use of the 5E model "helped foster higher-level thinking" (participant 3) and they witnessed, "how thoughtful and thorough the students were during the lesson" (participant 5). Additionally, 47% of participants reflected on their pedagogical strategies and its effectiveness in terms of student engagement and suggested revised pedagogical strategy for future instruction. Their quotes reflected the tendency of *outcome expectancy* where the participant is contemplating the impact of using different pedagogical strategies on student engagement and learning. For instance, in the excerpt below, a participant compared the two activities focused on the water absorption and the level of engagement the students had within each activity:

> Another topic was how water is absorbed by plants. The discussions were well paced and in-depth because we related the experiments to what happens to plants when they receive water. I think it would have been better if we only did the sugar cube activity since the children were engaged in that more than the sponge activity. They could physically see how the water went up in the cubes since the cubes were white and the water was colored blue. I would change the sponge activity for future. This activity was too quick, and the children did not seem engaged with it. As for my personal growth, I realized that I need to work on my pacing. (Participant 3)

Teacher Attributes to Support Student Learning

We, as researchers, looked at the teacher attributes that participants described in their reflections that they believed are important for successful science teaching. Three teacher attributes that participants commonly described for effective science instruction were (1) preparing the materials needed for the hands-on activities (56%), (2) staying organized (31%), and (3) focusing on how to use materials with young children to help them stay on task (13%). One participant shared an unanticipated challenge with an activity that involved balloons and a pencil to compare the effects of gravity and air resistance when dropping them from a height. While their group prepared the materials ahead of time, including balloons already inflated and ready to use, they realized that balloons posed additional distraction. Participant 7 used this example productively in her reflections to discuss the changes she could make in future, as she mentioned:

> We had all of our supplies ready to go throughout the process to ensure that there were limited distractions and waiting. However, we wish we could to keep these materials out of

> sight during some aspects of the lesson because the inquiry to wanting to use these balloons and what they were for created a distraction even before we started our lesson. If this was completed in our own classroom, we could adjust for this, as we would know what resources we had and places to prepare and hide the materials for the lesson.

Others noted that careful planning and organization is the key for effective teaching as one participant mentioned, “To implement this lesson effectively we needed to be planned and organized in what we were teaching. I believe I was on the right track in my planning and implementation, though there is still a lot of room for improvement.”

Assessment Strategies to Assess Student Learning

About 60% of participants realized the importance of seamless assessments in science teaching and indicated to incorporate assessments in their future lessons more efficiently, such as probing questions for students to think deeply. As Participant 12 said, “I felt much more prepared to ask guiding questions during this lesson than I had in the past. I paid more attention to thinking of deep questions that would help students answer the focus question without giving the answer away.” However, we also noted that 31% participants experienced challenges in implementing assessments, as one participant wrote, “it [the assessment] did not go the way it was structured. Our paper for the final assessment didn’t print correctly, as we did not realize about the page margins, so it turned into a worksheet instead of a flip book, and it ended up working not so well” (Participant 2). It appeared that participants felt frustrated with assessments not working the way they intended, as another participant shared “Even though we made the chart easier for students to understand I think that they were not well explained” (Participant 5).

Challenges Associated with Classroom Teaching

Broadly, the challenges that participants described in their written reflections belonged to three categories: (1) classroom management and student behaviors (44%), (2) responding to students’ questions

(49%), and (3) access to resources and technology (7%). Many participants shared that the practice teaching was their first experience teaching science in a formal setting, and therefore, they did not know what to expect. For instance, participants struggled to engage students with varying learning abilities at once; for instance, participant 6 shared, “a student that was very quiet but eager to learn and another student that was louder and easily distracted and also a runner.” Other participants described situations in which they were not able to provide satisfactory answers to student questions, which led to increased self-doubt in their preparation in the science topic. One participant shared, “I can honestly say I could have been more prepared for the student’s statements and questions” (Participant 1). Notably, the participants suggested using more technology in teaching science and believed that this would influence student engagement; for instance, one participant said, “I would also include a video to teach the children about energy. The video could extend students’ learning and give them another way to connect to the material” (Participant 5). The excerpt, hereby, suggests that the participant is thinking deeply about ways to improve their instruction (using videos, for instance), which would help seek the *outcomes* they expect to achieve, which in this case is children learning about the concept of energy.

Discussion

The study contributes to the existing literature on preservice science teaching self-efficacy in many unique ways. First, the study explores *how* and in *what* ways PETs’ self-efficacy beliefs are shaped as they gain new experiences in the context of science methods courses and field experiences. Second, unlike prior studies, this study considered reflective thinking as an *ongoing process* that allows PETs to confront and contest their prior views about science teaching in light of new science learning and teaching experiences in the course. Specifically, we utilize preservice elementary teachers’ reflective practice as an analytical lens to understand what critical elements of the science methods course and field teaching do preservice teachers emphasize, and how the descriptions of episodes from their field teaching relate to the development of science teaching self-efficacy. Lastly, in this investigation, we have utilized both quantitative and qualitative approaches rather than a single qualitative or quantitative methodological approach. We argue that unlike prior studies on self-efficacy where the methodologies have often been restricted to using qualitative approaches and relatively small sample sizes, utilizing multiple methods is critical given the complex nature of the construct.

Development of Science Teaching Self-Efficacy

The findings revealed significant positive gains in participants' science teaching self-efficacy beliefs at the end of the semester. Comparing the two PSTE and STOE subscales, we found a larger positive effect on PSTE than STOE. These results are consistent with other empirical studies in the literature who also found less change in PETs' STOE beliefs than in their PSTE beliefs within the context of science methods and content courses (Cantrell, 2003; Hechter, 2011; Menon & Sadler, 2016). While one may expect that field experiences will generate large changes in STOE given that these experiences provide PETs with first-hand teaching experience, importantly, PETs also experience challenges, especially when teaching science for the first time to elementary-level students, as in the case of this study.

The qualitative trends identified in the participants' narratives from their science autobiographies and reflections support the quantitative results. Evidence from the science autobiographies from the beginning of the semester suggested that PETs' views of science teaching were complex and had evolved through years of formal and informal interactions with science in formal and informal settings and that multiple factors contributed to the formation of their initial science teaching self-efficacy. In general, the participants' descriptions concerned their connections with science topics, whether they found science topics relevant to their lives, and their personal success or failure in prior science courses. Negative dispositions towards science before entering science methods courses interfere with preservice teachers' feelings of preparedness and their science teacher self-images (Knaggs & Sondergeld, 2015; Menon & Sadler, 2016).

During the field experiences, in-class interactions with elementary students seemed to have a significant impact on participants' self-confidence and self-efficacy. As discussed in previous studies, interactions such as those with elementary students, mentor teachers, college instructors, peers, are influential in the development of one's self-efficacy (Bautista, 2011; Hancock & Gallard, 2004; Leonard et al., 2011). As highlighted in participants' reflections, the development of self-efficacy beliefs was associated with successes and challenges with planning for activities and material use, choice of pedagogical strategies and assessments, and implementing science lessons. Our findings from the reflection narratives provide evidence that meaningful and successful experiences in the field can overcome negative associations with science, to a larger extent, and help PETs develop stronger senses of science teaching self-efficacy. Even with the positive changes in self-efficacy, there were areas where PETs felt challenged, for instance, in the use of assessments. Often times, the focus of the science methods courses are learning reform-based pedagogies; it is important to include assessment practices for preservice teachers to develop the knowledge base related to the use of assessments.

In regard to developing reflective thinking, the intention of reflecting and describing past *critical* incidents is to help preservice teachers to "move beyond description" (Davis, 2006, p. 294) towards making connections to their future science teaching. It is not surprising that scaffoldings are needed for preservice teachers' to be able to reflect deeply on their prior experiences at the beginning of the semester. As noted in the literature, it is unlikely that preservice teachers would reflect on their experiences and find deeper connections, as experts would, when they first enter science methods courses (Davis, 2006; Lee, 2005). During the methods course, it is therefore important to hold a "debrief session" with preservice teachers immediately after their teaching preferably, as in the case of this study. This debriefing will allow opportunities for shared dialog to share successes and challenges they experienced in classroom teaching. At the end of the semester, however, a majority of the participants' narratives contained deeper and clearer connections between their field experiences and their professional growth as science teachers. Participants' suggestions for future science teaching (such as the use of videos or other pedagogies) were linked to the student outcomes (student engagement or learning), which suggest that participants thought diligently what to improve for their future instruction. The themes from the reflection papers indicate an apparent shift in the participants' self-efficacy, as they were able to develop a more comprehensive and sophisticated view of science teaching (Davis, 2006). This finding is consistent with studies that have suggested that the field-based science methods courses provide an appropriate context in which self-efficacy is shaped (Bautista, 2011; Hancock & Gallard, 2004; Leonard et al., 2011).

Implications

The study has implications for preservice teacher education programs and future research. First, science educators must include a field-based component within science methods courses for preservice teachers to gain first-hand teaching experiences. Practice science teaching experiences are valuable (Mulholland & Wallace, 2001) and may also help in smooth transition into future classrooms. Second, this research reported the importance of reflective practices in shaping PETs' self-efficacy. Consequently, we recommend that science methods courses include multiple opportunities for reflection so that PETs can challenge their prior beliefs of science teaching. Opportunities to develop preservice teachers' reflective thinking skills may include targeted debriefing sessions on field teaching, video-stimulated reflections where preservice teachers can watch themselves and reflect on various aspects of their teaching, and writing reflective diaries on teaching episodes (Hawkins & Park Rogers, 2016; Kleinknecht & Schneider, 2013). Reflection on teaching helps preservice teachers "see what matters" (Davis, 2006, p. 281). Third, this research identified a possible link between reflective practices and science teaching self-efficacy. We recommend acknowledging this link while designing science methods courses. We realize that more studies are needed to explore the connections between reflective practice and self-efficacy and to understand how the two constructs interact to shape science teaching self-efficacy in the long term.

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