J Sci Teacher Educ (2016) 27:649–673
DOI 10.1007/s10972-016-9479-y

Preservice Elementary Teachers' Science Self-Efficacy Beliefs and Science Content Knowledge

Deepika Menon[1] · **Troy D. Sadler**[2]

Published online: 1 July 2016

Abstract Self-efficacy beliefs that relate to teachers' motivation and performance have been an important area of concern for preservice teacher education. Research suggests high-quality science coursework has the potential to shape preservice teachers' science self-efficacy beliefs. However, there are few studies examining the relationship between science self-efficacy beliefs and science content knowledge. The purpose of this mixed methods study is to investigate changes in preservice teachers' science self-efficacy beliefs and science content knowledge and the relationship between the two variables as they co-evolve in a specialized science content course. Results from pre- and post-course administrations of the Science Teaching Efficacy Belief Instrument-B (Bleicher, 2004) and a physical science concept test along with semi-structured interviews, classroom observations and artifacts served as data sources for the study. The 18 participants belonged to three groups representing low, medium and high initial levels of self-efficacy beliefs. A repeated measures multivariate analysis of variance design was used to test the significance of differences between the pre- and post-surveys across time. Results indicated statistically significant gains in participants' science self-efficacy beliefs and science conceptual understandings. Additionally, a positive moderate relationship between gains in science conceptual understandings and gains in personal science teaching efficacy beliefs was found. Qualitative analysis of the participants' responses indicated positive shifts in their science teacher self-image and they credited their experiences in the course as sources of new levels of confidence to teach science. The study includes implications for preservice teacher education programs, science teacher education, and research.

✉ Deepika Menon
dmenon@towson.edu

[1] Towson University, 8000 York Road, Towson, MD 21252, USA

[2] The ReSTEM Institute: Reimaging and Researching STEM Education, University of Missouri, Columbia, MO, USA

Keywords Preservice teacher education · Self-efficacy beliefs · Science content knowledge

Introduction

Preparing high-quality elementary science teachers continues to be an area of concern and one of the major foci of science education reforms (AAAS, 1993; NRC, 1996, 2012; NGSS Lead States, 2013). Despite calls and systemic reform initiatives to improve science teaching in elementary classrooms, recent surveys of elementary teachers suggest that relatively few (33 %) feel prepared to teach science and even fewer feel prepared for teaching physical science (Banilower et al., 2013; Trigstad, Smith, Banilower, & Nelson, 2013). While much of the conversation about elementary teacher preparation has focused on the issue of limited science content preparedness (Appleton, 2006; Hechter, 2011), close attention has also been paid to self-efficacy beliefs (Cantrell, Young, & Moore, 2003; Kazempour & Sadler, 2015; Leonard, Barnes-Johnson, Dantley, & Kimber, 2011; Palmer, 2006a). Researchers have documented critical links between self-efficacy beliefs and teaching practices (Bandura, 1997; Tschannen-Moran, Hoy, & Hoy, 1998) as well as teacher behaviors (Dembo & Gibson, 1985) and attitudes (Mulholand & Wallace, 1996). Teachers' self-efficacy has also been associated with student learning outcomes (Bandura, 1977, 1982; Tschannen-Moran et al., 1998) and achievement (Tosun, 2000). While science content knowledge is considered as one of the limiting factors for effective science instruction, researchers working in the field have different explanations regarding how science content knowledge may interact with science self-efficacy beliefs.

The intent of this study is to explore relationships between preservice teachers' science self-efficacy beliefs and science conceptual understandings in the context of a specialized physics course designed for elementary preservice teachers. Since science content courses are an integral part of teacher training, it is reasonable to expect that experiences within these courses can impact science self-efficacy beliefs.

Theoretical Background

The self-efficacy construct, derived from social cognitive theory, was first conceptualized by Bandura (1977) as a judgment of one's own capabilities to perform actions that they believe could lead to desired results. Bandura claimed that self-efficacy beliefs are the strongest predictors of motivation and performance (1986). Self-efficacy has emerged as an influential construct suggesting that human behavior is affected by the beliefs people hold. Self-efficacy was further conceptualized as a dynamic construct that can change with experience and has a "mobilization component" (Gist & Mitchell, 1992, p. 185) that helps individuals to adapt themselves to complex situations (Bandura & Wood, 1989; Gist & Mitchell, 1992).

According to Bandura, the concept of self-efficacy beliefs consists of two dimensions: outcome expectancy and personal efficacy. While outcome expectancy corresponds to a person's belief that his/her behavior will produce desired outcomes, personal efficacy is a person's confidence to execute actions leading to the achievement of a desired goal. Guskey and Passaro (1994) suggest that both dimensions of self-efficacy are significant for teaching but act independently of each other. For instance, elementary teachers might expect that certain actions and classroom behaviors performed well will bring desired results in student learning (high outcome expectancy) but might not have sufficient confidence to execute those actions (low personal efficacy). In recognition of the significance of self-efficacy, efforts have been made to develop valid and reliable measurement instruments (Bleicher, 2004), and the Science Teaching Efficacy Belief Instrument-B (STEBI-B) focuses specifically on assessing science teaching self-efficacy among preservice teachers (Enochs & Riggs, 1990). It has two scales: personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE).

Literature on educational beliefs places self-efficacy as a subset of a broader belief structure that influences individuals' judgment and actions (Nespor, 1987; Pajares, 1992). Several researchers relate these belief systems to the development of positive attitudes and teachers' behavior (Nespor, 1987; Pajares, 1992). Furthermore, self-efficacy beliefs are situational, context, and subject matter specific (Bandura, 1997, Tschannen-Moran et al., 1998). This suggests that the self-efficacy beliefs that teachers hold for other subjects may have little effect on their science teaching efficacy beliefs. It is important to note that many research studies have used both self-efficacy and confidence interchangeably; therefore, while highlighting specific studies in "Literature Review" section below, the usage of terms is preserved from the original authors. However, for the purposes of the current study, we utilize Bandura's framework of self-efficacy that includes "confidence to teach science" as one of the dimensions of self-efficacy beliefs.

Literature Review

Teacher Self-Efficacy

Self-efficacy beliefs play a major role in determining teaching practices including the choice of instructional activities, organization of lessons, and preparation to handle challenging situations (Bandura, 1997). Applied to elementary science teaching, researchers have suggested that highly efficacious teachers are more successful (Appleton & Kindt, 2002), more willing to take challenges (Ramey-Gassert, Shroyer, & Staver, 1996), and more committed to teaching science (Riggs & Enochs, 1990). Additionally, teachers with high self-efficacy are more likely to incorporate inquiry-based practices into their teaching and creating learner-centered environments in their classrooms (Watters & Ginns, 2000). Low-efficacious teachers tend to rely on books and prescribed materials, which limit students' thinking and creativity for understanding science concepts (Ramey-Gassert & Shroyer, 1992). For instance, Appleton and Kindt's (2002) study confirmed that beginning teachers with low confidence preferred limited engagement strategies such as worksheets over hands-on activities to teach science.

There is consensus among researchers exploring teacher education that the beliefs held by preservice teachers are carried with them to their future classrooms (Enochs & Riggs, 1990; Kazempour & Sadler, 2015; Ramey-Gassert & Shroyer, 1992). Because experiences shape teachers' beliefs toward science teaching and overall instructional practices, a number of studies have investigated preservice teachers' experiences within teacher preparation courses. The vast majority of these studies are conducted within the context of science methods courses, and the methodologies are restricted to using either a qualitative or a quantitative approach. Most of the reported literature suggests that science methods courses can enhance self-efficacy beliefs (Avery & Meyer, 2012; Brand & Wilkins, 2007; Gunning & Mensah, 2011). Rice and Roychoudhury (2003) found that the preservice teachers enrolled in science methods course benefitted from the modeling of appropriate instructional strategies such as learning cycle lessons, hands-on activities, and group discussions. Other studies reported that watching video cases of expert teaching stood out as a strong source of self-efficacy (Settlage, 2000; Yoon et al., 2006). Palmer (2006b) reported that students benefited from exposure to effective science instructional strategies and role playing as in the elementary classroom. Interestingly, most of these studies cited concerns related to how preservice teachers' preparedness in science content courses prior to methods coursework may affect their science self-efficacy beliefs. Rice and Roychoudhury's (2003) suggested that lack of science knowledge was a major hindrance to the development of confidence for science teaching. Yoon et al. (2006) also reported that lack of prior science knowledge was the main accounting factor for the participants' low self-efficacy. These findings suggest that negative dispositions toward science and limited science knowledge prior to entering methods courses may influence preservice teachers' science self-efficacy beliefs.

Science Self-Efficacy and Science Content Knowledge

The fact that many elementary teachers have low science self-efficacy raises concerns about preservice teacher education programs including questions about the effectiveness of the science content courses that preservice elementary teachers take. Several studies suggest that preservice teachers are often subjected to formal science coursework based on ineffective teaching practices that can lead to more negative attitudes and beliefs toward science teaching (Mulholand & Wallace, 1996; Rice & Roychoudhury, 2003). These negative experiences along with inadequate science content preparation restrict preservice teachers' ability to teach science (Jarrett, 1999; Mulholand & Wallace, 2001) and, in some cases, can lead to avoidance of science teaching altogether (Appleton & Kindt, 1999).

Studies that explored the link between science self-efficacy and science content knowledge have yielded mixed results. The findings from Hechter's study (2011), consistent with earlier work by Jarrett (1999), suggested that the number of science content courses taken by preservice teachers and perceptions about their prior school science experiences were positively correlated with science self-efficacy. Other research has shown associations between preservice teachers' self-reports of science experiences and content knowledge with self-efficacy (Bleicher & Lindgren, 2005; Velthuis, Fisser, & Pieters, 2014). In contrast, Tosun (2000) found that student achievement in science did *not* contribute to participants' perceptions of science. Students from high- and low-achievement groups had similar negative feelings toward science, which had an impact on their science teaching self-efficacy.

A few studies have focused on changes in self-efficacy in the context of science content courses, but they have not explicitly explored the relationship between science content knowledge and self-efficacy beliefs. Bergman and Morphew (2015) investigated the effectiveness of a science content course and found significant increases in preservice elementary teachers' science self-efficacy beliefs by the end of the course. These results are consistent with findings from Baldwin (2014) in which a geology course designed for elementary education majors led to increases in participants' PSTE beliefs.

Focus of this Research

We were interested in investigating the relationship between preservice teachers' science self-efficacy beliefs and science content knowledge and the relationship between the two variables as they co-evolve in a specialized science content course. A "specialized content course" refers to a science course specifically designed for preservice elementary teachers to learn to integrate understanding of science concepts with pedagogical models advocated by national reform efforts (Crowther & Bonnstetter, 1997). The relationship between content knowledge and self-efficacy beliefs has been suggested in the literature but has not been systematically explored in the context of specialized science content courses. We explore the following three research questions in the context of a specialized physics content course.

1. How do preservice elementary teachers' science self-efficacy beliefs (personal science teaching self-efficacy—PSTE and science teaching outcome expectancy—STOE) change during a specialized physics content course?
2. What is the relationship between preservice elementary teachers' science self-efficacy beliefs (PSTE and STOE) and conceptual understanding of physics prior to and after their participation in the specialized physics content course?
3. What is the relationship between changes in science self-efficacy beliefs (PSTE and STOE) and changes in science conceptual understandings?

Methodology

Design

This research study utilized an embedded mixed methods design (Tashakkori & Teddlie, 2010) including three phases of data collection and analysis. A mixed methods design can enhance understandings of complex phenomena and provide a more comprehensive picture of the phenomena than a single method design (Morse & Niehaus, 2009). Both science self-efficacy and its relationship with science conceptual understanding are complex phenomena; thus, the mixed methods design was well suited for this study. While quantitative results are used to document changes in science self-efficacy beliefs and its relationship with science conceptual understandings, qualitative results enhance the understanding of the processes related to how and why these changes occurred within the research context.

This research used sequential mixing procedures that proceeded in three sequential phases: an initial quantitative phase, a qualitative phase during the semester, and a final quantitative phase at the end of semester. The initial quantitative phase was used to inform selection of participants for the qualitative data collection, which allowed for more in-depth exploration of participants' beliefs and experiences. The final stage was important for investigating the research question focusing on the relationship between participants' science self-efficacy beliefs and science conceptual understanding. The details of the three phases of "Data Collection and Analysis" are provided in the sections below.

Research Context

This study was conducted in a specialized physics content course at a large Midwestern university. The 5-credit-hour course, taught within the physics department, was specifically designed for early childhood and elementary education majors. The course was structured as a lecture–laboratory format emphasizing instructional strategies such as inquiry-based hands-on investigations, collaborative team work, and group discussions, all methods that preservice teachers are expected to use in their future science teaching. The course focused on preparing preservice elementary teachers to teach physical science topics aligned with K-6 curricula including electricity, magnetism, force, and motion. In addition to student learning of basic physics principles and ideas, course goals included enhancing preservice teachers' inquiry skills by modeling inquiry-based instructional strategies such as the 5E learning cycle: engage, explore, explain, elaborate, and evaluate (Bybee, 1997), problem-solving skills, and understanding of the nature of science.

The curriculum, available as "Exploring Physics" (Chandrasekhar & Kosztin, 2012), consisted of three major topics including electricity, magnetism, and force and motion, which were divided into five units: (1) batteries, bulbs, and switches, (2) electrical circuits, (3) magnetism, (4) introducing forces, and (5) uniform motion. Each unit was divided into smaller units of instruction taught through the 5E learning cycle. Unit outlines and instructional activities were made available for students on an in-class smart board and an online course management site (blackboard). Students worked in groups of three at their working tables to conduct small scientific investigations, projects, and group presentations. A variety of formative and summative assessments running seamlessly within the phases of learning cycle were a prominent feature of the course.

Sample Instructional Sequence: *Electric Circuits*

We describe the learning cycle employed as a means of helping students learn about electric circuits as typical example of teaching in the course. The purpose of the lesson was to help students understand the concept of a complete circuit. The students were first asked to think and discuss what is needed to light a light bulb (the *engage* phase of the 5E model). Students were further encouraged to think about what materials other than the bulb they would need to light a bulb and to draw the circuit on their white boards. After a whole group discussion on students' initial ideas, each group was given six different circuit arrangements to predict the ones that would light the bulb and to provide reasoning for their choices. Once students shared their ideas, they were provided with the materials (one bulb, one battery and one wire) to test each of the six circuits and record their observations on the worksheet provided (*explore*). Students shared their recorded data and provided evidence to explain their findings related to why their predictions were correct or incorrect. Students were then asked to generate their own explanations of a complete circuit and the conditions for making a bulb light. The discussion led students to conclude that two contact points of bulb and battery should be connected in a way to make a closed-loop circuit (*explain*). Students were further challenged to draw circuits for lighting one bulb with two wires and a battery and two bulbs using two wires and a battery (*extend*). The class discussed each group's predictions followed by testing the circuits. At the close of the lesson, each student was provided with various circuit arrangements and asked to explain whether the bulb would light in each case (*evaluate*).

Participants and Sampling

A total of 62 preservice teachers enrolled in the course over three semesters and were invited to participate in the study; of these individuals, 51 volunteered to participate. The STEBI-B and a physical science concept test were administered at the beginning of the semester, and the STEBI-B scores were analyzed to select three distinct groups of participants for interviews. Students whose scores were in the top quartile were labeled the high self-efficacy group; students whose scores were in the lowest quartile were labeled the low group; and the remaining students were classified as the middle self-efficacy group. Each group (high, medium, and low) consisted of six preservice teachers for a total of 18 interview participants. This subsample included 17 females and one male; 17 were sophomores, and one was in her junior year. The pool consisted of 16 Caucasian and two Hispanic students, and none of them had formal teaching experience. Table 1 displays demographic information and prior science experiences.

Instruments: STEBI-B

The STEBI-B consists of 23 items on a five-point Likert scale with two sub-scales: PSTE and STOE. The PSTE scale measures personal beliefs about effective teaching, and the STOE scale measures preservice teachers' beliefs about student

Table 1 Demographics and personal science experiences of participants

Group (each group $N = 6$)	Age (years)	No. of science courses taken in high school	Informal teaching experiences	Description of Science experiences	Informal science experiences (outside classroom factors)
Low	19–20	Four courses ($N = 3$), three courses ($N = 2$), five courses ($N = 1$)	Volunteer for an elementary classroom ($N = 1$)	Challenging, required extra effort, struggled to get through	Science talks, media stories, elder sibling's books
Medium	19–20	Four courses ($N = 3$), three courses ($N = 2$), five courses ($N = 1$)	Tutoring a child ($N = 1$)	Required more effort, some science classes were better than others	Science kits and games, excursion to wildlife
High	19–20	Four courses ($N = 5$), seven courses ($N = 1$)	Tutoring a child ($N = 3$), volunteer for an elementary classroom ($N = 1$)	Fun and interesting, loved the material and the surprise element of it	Media—National Geographic channel, Discovery channel

outcomes as a result of their science teaching. Scores on the PSTE scale (13 items) can vary between 13 and 65, and scores for the STOE scale (10 items) can range from 10 to 50 with higher scores corresponding to higher self-efficacy. Reliability of the instrument for this sample was explored using Cronbach's α. Cronbach's α values show that the internal consistency of measurement for pre- and post-PSTE is .8 and .88, respectively. These values are well above the accepted lower limit of .65 (Chandrasegaran, Treagust, & Mocerino, 2007). The reliability coefficients for pre- and post-STOE were .63 and .70, respectively. We noticed slightly lower values for the pre-STOE scale, but there was an increase in reliability at the posttest. The low reliability value for pre-STOE may be explained by the fact that students may not have fully developed views on outcome expectancy at the beginning of the semester.

Instruments: Physical Science Concept Test

The physical science concept test consists of 15 multiple choice items. The test includes items on electricity, magnetism, and force and motion to assess participants' conceptual understandings on the most prominent science concepts covered in the course. The instrument was well aligned with both the course content and the physical science often prioritized in K-6 curricula. The items were selected from three sources: (1) Determining and Interpreting Resistive Electric Circuit Concepts Test (DIRECT), a concept inventory that assesses student difficulties and misconceptions regarding direct current resistive electric circuits (Engelhardt & Beichner, 2004); (2) Force Concept Inventory (FCI), a concept inventory designed to detect students' ideas about Newtonian concepts of force (Hestenes, Wells, & Swackhamer, 1992); and (3) the National Science Teachers Association (NSTA) PD Indexer tool, an online resource developed to identify gaps in students' understanding of specific science topics including physics concepts targeted in this study. Careful attention was paid while selecting the items from each instrument to match the content and assessment goals of the course. An example of such an alignment is shown in Table 2. The initial test consisted of 20 items; five of the items were discarded following analysis using Full-Information Factor Analysis (FIFA). The final version consisted of 15 items.

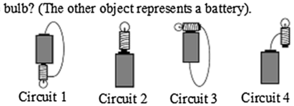
Face and content validity of the physical science concept test was established by an expert panel who reviewed the instrument and provided feedback. The panel consisted of professors from physics (two), science education (three), nuclear engineering (one), as well as doctoral students from physics (three) and science education (two). The panel provided feedback on whether items aligned with the assessment goals. The items with low agreement among reviewers were revised or reworded. The test was administered to 110 college students (not involved in the main study featured within this report). Construct validity was established by factor analysis using classical test theory (CTT) (Osterlind, 2006). The TESTFACT software was used for FIFA, which provides information on internal structure of the test, item characteristics, and factor loading for each item. All items have a facility index, a measure of item difficulty, between .40 and .65. An item discrimination index was calculated through point bi-serial correlation coefficients, and all items on the final instrument exceeded .2. The final version of the test was administered to 47 college students (another unique sample). The Cronbach's α value for this version was .66, which exceeds the standard .65 threshold for acceptable internal consistency (Chandrasegaran et al., 2007; Nunnally & Bernstein, 1994).

Data Collection and Analysis

The second phase of data collection involved semi-structured interviews with selected participants ($N = 18$): two interviews—one conducted within a few weeks of the beginning of the semester and the other a few weeks before the semester concluded. The purpose of the initial interview was to gain insights into participants' science experiences prior to college that may have an impact on their science self-efficacy beliefs. The purpose of the second interview was to gather information on how participants express their science self-efficacy beliefs after participating in the specialized physics content course. All interviews were conducted individually and audio-recorded; the audio files were fully transcribed for analysis. In addition, observation data were collected twice a week during class sessions. The field notes taken were recorded in a format suggested by Corsaro (1981, 1985): field notes (direct observations), methodological notes (methods that are used to take observations, time, place, how it is being recorded), theoretical notes (personal explanations/interpretations in light of the literature read), and personal notes (contextual factors that may influence while taking observations).

A grounded theory approach (Strauss & Corbin, 1988) was used to analyze the qualitative data. According to Strauss and Corbin (1988), grounded theory

Table 2 Example of course concepts aligned with assessment goals

Topic	Concept (sub-concepts)	Assessment goals	Representative test item (selected from DIRECT 1.2)
Electricity	Conservation of charges in a bulb and complete circuit: (1) understand the contact points of the bulb, how the charges flow in the bulb, (2) understand the concept of complete circuit in order to light the bulb and (3) understand the conservation of charge in a variety of circuits	(1) Understand and apply the concept of conservation of charge in a light bulb and other circuits (2) Understand and apply the knowledge of how a bulb works (two contact points) in a complete circuit	Which circuit(s) will light the bulb? (The other object represents a battery). (A) Circuit 1 (B) Circuit 2 (C) Circuit 3 (D) Circuits 1 and 3 (E) Circuits 1, 3, and 4 

techniques "allow theory to emerge from the data, are likely to offer insight, enhance understanding, and provide a meaningful guide to action" (p. 12). The analysis began with open coding of the interview transcripts: Raw data were read and re-read for common characteristics, factors, or events as described by participants to assign initial codes. Second, initial codes were grouped to generate categories or themes, and some categories were divided into sub-categories. To ensure the trustworthiness of the themes that emerged from the data, an expert in qualitative analysis was consulted to cross-check emergent themes from the data. Once all of the interview data were analyzed by open coding, an axial coding process was employed. Axial coding allowed reassembling of the data where each category and sub-categories were revisited to draw meaningful links between them. This technique was helpful for finding meaningful patterns that explain the general phenomena rather than singled out terms and events. This process of creating relational statements (Strauss & Corbin, 1988) was continued until saturation was reached. The final analysis step was a theoretical comparison, which is similar to constant comparison methods. In this process, data were continuously reviewed to compare incident to incident within and across categories that either reduced existing categories or formed new categories (properties and dimensions). Finally, comparisons were made based on prior knowledge and the existing literature. The analysis of observation data was similar to the analysis of the interviews and was used to triangulate findings that emerged from analysis of the interviews.

The third phase of data collection and analysis occurred at the end of the semester. Both the STEBI-B and the physical science concept test data were analyzed using Statistical Package of Social Science (SPSS) software. A pre- and post-repeated measures multivariate analysis of variance (MANOVA) design was used to evaluate the significance of differences between data collected at the two time points. The F statistic calculated from Wilks's lambda was used to test the significance of differences between the mean vectors across time. The multivariate null hypothesis was that there were no significant differences between the pre- and post-self-efficacy mean scores over time. The content pre–post-scores were also included in the analysis to reduce the Type 1 error in the overall analysis. The MANOVA design was a suitable approach for this study as it allowed for examination of several dependent variables (outcomes) at the same time (Field, 2009; O'Brien & Kaiser, 1985). Partial eta squared (η^2) and Cohen's *D* were used as estimates of effect size. Correlational analysis using a Pearson product–moment correlation coefficient (r) was calculated to investigate the relationship between science self-efficacy beliefs and science conceptual understandings.

Results

Changes in Science Self-Efficacy Beliefs

The study explored changes in preservice teachers' science self-efficacy beliefs (PSTE and STOE) during their participation in the specialized physics content course. Descriptive statistics for self-efficacy subscales and conceptual understanding are presented in Table 3. Multivariate tests, presented in Table 4, showed a significant difference between the mean vectors across time [$\Lambda = .281$, F (3, 48) = 40.193, $p \ll .001$, $\eta^2 = .719$]. Univariate tests showed statistically significant changes in all the three outcome variables: PSTE, STOE, and Content (Table 5). The practical significance of these effects, as inferred by partial η^2 values, was higher in PSTE as compared to STOE, explaining 65.6 % of the within-subject variance accounted for by PSTE and only 17.8 % of the variance accounted for by STOE. Because calculation of partial η^2 may induce the risk of overestimation of effects (Levine & Hullett, 2002), Cohen's D was also calculated. Using Cohen's (1988) suggested norms, large effect size for the changes in PSTE ($d = 1.24$) and Content ($d = 1.15$) and a moderate effect size for STOE ($d = .57$) were found.

The interview responses supported the quantitative results that showed significant gains in participants' self-efficacy beliefs. The existing literature on preservice

Table 3 Descriptive statistics on variables for self-efficacy and conceptual understanding

Variable	Mean	SD	Min	Max	Skewness	Kurtosis
PSTE						
Pretest	44.76	6.19	31	59	−.114	.164
Posttest	51.80	6.03	36	63	−.410	−.049
STOE						
Pretest	34.67	3.66	28	43	.509	.101
Posttest	36.78	3.81	31	47	.615	.333
Content						
Pretest	5.98	2.44	2	12	.162	−.570
Posttest	9.19	2.74	2	13	−.525	−.786

Maximum possible scores: PSTE = 65, STOE = 50, Content = 15

Table 4 Multiple analysis of variance ($N = 51$)

Within-subject effect		Value	F	Hypothesis df	Error df	Sig.	Partial η^2
Time	Wilk's lambda	.281	40.913[a]	3.000	48.000	.000	.719

Within-subject design: time

[a] Exact statistics, $\alpha = .05$

Table 5 Univariate tests for all measures

Measure	Type III sum of squares	df	Mean square	F	Sig.	Partial η^2	Cohen's D
PSTE	1263.539	1	1263.539	95.295[a]	.000	.656	1.24
STOE	114.353	1	114.353	10.795[a]	.002	.178	.57
Content	263.686	1	263.686	71.146[a]	.000	.587	

[a] $\alpha = .05$

teacher self-efficacy suggested that the positive expressions of self-efficacy for science teaching could be demonstrated by preservice teachers' affirmation of confidence in their ability to teach science and through their explanations of themselves as future science teachers (Gunning & Mensah, 2011). The qualitative evidence of the increases in self-efficacy beliefs were demonstrated through the ways in which elementary preservice teachers talked about themselves as future science teachers and their confidence to teach science. In this study, the participants' perceptions of themselves as science teachers were defined as science teacher self-image. The sections below address the development of participants' "Science Teacher Self-Images" and confidence supported by interview data. The excerpts from participants' interviews are reported such that the individual, her/his group (high, medium, or low), and data source (first or second interview) are evident. For example, 1M-2 refers to the second interview with first participant in the medium group.

Science Teacher Self-Image

Initial Ideas

In this section, the participants' initial science teacher self-images are discussed followed by the evidence supporting shifts in their views of self as science teachers. At the beginning of the semester, all participants were asked about how they see themselves as future science teachers. The participants' initial responses varied across groups (i.e., the high, medium, and low groups). A majority of participants from the low group did not identify themselves as science teachers. For example, a participant from the low group responded, "I do not see myself as a science teacher. Science has never been my strong point…I guess right now I do not have that knowledge" (3L-1). Other low-group participants indicated hesitation to teach science due to either lack of science content knowledge, lack of sufficient science experiences, or lack of science teaching experiences (see Table 6 for more examples).

In contrast to these responses, which suggested negative science teacher self-images, five of the six high-group participants had positive images of themselves as science teachers. Their responses indicated strong desire to teach science and that "understanding science is important for their future kids" (5H-1). These participants cited strong affinity toward science originating from positive experiences in prior science classes. For instance, a high group participant stated, "I loved the material in my science classes, and I would love teaching it [science] and hopefully inspire people to like it as much as I like it because I like teaching science" (1H-1).

The one high group participant who shared a more negative self-image as a science teacher talked about her own struggles as a science learner: "I have struggled in it [science] a little bit…like it is not my favorite interest so I don't think I would be able to teach it very well right now" (4H-1). This participant was placed in the high group based on her high scores on the pre-STEBI-B; however, her responses during the first interview seemed to contradict her quantitative scores.

Table 6 Science teacher self-image of group participants (at the beginning and end of the course)

Group	Participant	First interview	Second interview
Low	4L	*No* [science teacher self-image], right now *I only took like two science classes in high school*, just like the basics we had to have and that is kind of the *only science experience I have so I would not know how to teach it*	I mean I think I would be like *better prepared now to teach* it. I still need some work but I feel like *before I could not see myself teaching science at all but I could see myself teaching some now*
	5L	*No* [science teacher self-image], *I have never thought it [science] as my best subject* or anything. I mean I think science is interesting, I just don't, I am not super good at it like *it is not my thing*	*I definitely think I would be better teaching physics. I understand more*, because this is more like a surface level class than really in depth and *I think that is probably I would be teaching* so I think I have a better understanding of it
Medium	1M	*No, I don't* [science teacher self-image]. *I do not like science.* I have never been interested, I guess. I don't enjoy I guess sitting and learning how the inside of things work	As I have gone through this class *I see myself more so as a science teacher as it would not be so difficult.* I would not have ever thought about teaching science before. And now I feel like I have opened my mind more than before. *Yes, I am more likely to teach a science class, I feel like I am more prepared*
	4M	*Not particularly no* [refers to self-image of a science teacher]. I am an early childhood education major so you know *I will be teaching everything I guess so*. Not really, I mean science… like when I was in school stuff, I mean I was good at it but I never…*it was not one of my favorite subjects or anything*	*I think it (teaching science) will be a little bit easier…basically knowing some more stuff about the things that I would be teaching*. I don't know if I want to see myself specifically as a science teacher. Like I want to teach elementary level so I will teach all sorts of subjects and stuff. May be I mean *I can see how some of the stuff we have done in class I might be able to take to the classroom eventually*
High	1H	*I could definitely see myself as a science teacher*, I love the material [refer to science] and *I would love teaching it* and hopefully inspire people to like it as much as I like it because I like teaching science	*Yes, I definitely could see myself as a science teacher. I feel like I would go into an elementary school classroom and be able to teach* about circuits and how they worked and like the basics, I think I have a better understanding of the basics
	5H	*Yes [refers to self-image of a science teacher], I have always loved science and I think it is very important for kids* to have an understanding of science and natural world	*Yes. I have a better understanding so better be able to teach it.* Because I did really well in the class. *I understood all the concepts and I think that I could teach the class easily upon what we learned*

Interestingly, this participant said that she "had about roughly 5 and 1/2 years of science in high school" and added that "My teachers were really good. I liked my science classes" (4H-1). The positive comments made by her seemed to contradict her negative self-image of a science teacher, which makes this participant worth mentioning.

Two of the six medium-group participants expressed positive ideas associated with science teaching, similar to the trend observed with the high-group participants. The remaining four medium-group participants did not self-identify as science teachers. Their responses reflected two recurring themes: They were not particularly interested in science, and they saw themselves as elementary teacher generalists and not necessarily science teachers. A medium group participant stated, "Not really [refers to her future role as a science teacher], I mean science… like when I was in school and stuff, I mean I was good at it but it was not one of my favorite subjects or anything. I will be teaching everything I guess so" (4M-1). Table 6 presents representative excerpts of participants' interview responses from the first and second interviews. There are distinct patterns of shifts in participants' view of themselves as future science teachers when responses from both interviews are compared (where appropriate, critical words, or phrases are italicized).

End of Experience Views

Many participants' responses to the question of how they viewed themselves as science teachers indicated positive shifts in their science teacher self-images. There were noticeable positive shifts in ways that the low and medium-group participants talked about themselves as science teachers. A participant from the low group said, "I believe that I would be a better science teacher now than I would have before because I have the ideas now" (2L-2). These participants were asked to elaborate on *how* their view of self as science teachers changed. The majority stated that the ways in which the content was presented in the course provided them with ideas for future teaching. Specifically, the participants seemed to have benefitted from experiences they had in the course that allowed them to witness fun and engaging ways to teach science. A medium group participant shared, "Now I could teach a pretty good physics class. I find it a lot easier and I know that there are ways to make science fun" (4M-2). Conversely, all of the high-group participants' responses, except the individual who shared negative views in the initial interview, did not demonstrate shifts in their science teacher self-images; that is, they maintained their positive self-images as science teachers. The participant who initially expressed concerns with teaching science said in her second interview that "it is not that super challenging and I think I will be able to teach it pretty well" (4H-2).

The excerpts presented in Table 6 suggest that participants' positive science teacher images supported their personal science self-efficacy beliefs. Another set of interview questions were specifically designed to provide insights into participants' views on student learning outcomes as a consequence of their future teaching. For example, "do you think your science teaching will make a difference in your students' achievement? Why?" These questions prompted participants to think about their future students and the potential impacts of their teaching. Participants from all three groups indicated development of more positive outcome expectancies, but more participants from the high and medium groups, as compared to the low group, mentioned that they see themselves as effective science teachers. A frequent rationale for these beliefs related to their perceived abilities to make science fun and comprehensible for their students.

Most of the participants indicated that they witnessed ways to make science interesting and were willing to teach science in similar ways, so they believed that their future elementary students would also learn from them. These participants further elaborated that they were willing to incorporate teaching strategies that they found effective such as hands-on investigations. The excerpt presented below shows this tendency (relevant text is italicized):

> I hope that by me teaching it [science] to them [future students] that they can see how science is and just *hoping to show them kind of science can be fun like we did stuff that was fun*: making posters, different experiments so hopefully I can show them that it is fun and that *hopefully they would want to do well. Hopefully I will be able to help them learn*. (3M-2)

Improved Confidence for Teaching Science

In this section, the participants' initial levels of confidence for teaching science are discussed followed by evidence of participants gaining new levels of confidence. At the beginning of the semester, participants were asked to rate their confidence to teach science on a scale of 1 (very low) to 5 (very high). Initial confidence indicated by low-group participants ranged from 1 to 2, medium group between 2 and 3, and high group ranged from 3 to 5. When asked to explain their choices, a majority of participants from the low and medium group indicated a lack of science teaching experience and a lack of content preparedness as the two major factors for low levels of confidence. A participant from the low group offered the following explanation of her low confidence: "I have hardly *any confidence at all* if I were to teach science. I have struggled in science and math based courses and would not want to teach someone if I was not confident in it myself" (3L-1). Table 7 presents more excerpts from high, medium, and low-group participants' responses to their initial levels of confidence.

During the second interview, a majority of participants across all three groups credited their science experiences in the course as sources of new levels of confidence to teach science. When asked again to rate their confidence level for teaching science, the low-group participants' range increased to 3–4, medium-group participants chose 4 as their confidence level, and the high-group participants maintained their high confidence indicating their choices of 4.5 or 5. These participants felt confident in the content covered in the course and explicitly described that having a better understanding of content facilitated their confidence to teach it. As one participant mentioned: "Now that I have gotten through this course I am definitely a lot more confident in my knowledge of these ideas that I can present to the students in the future. I think I do have a fair amount of confidence in being able to teach this to students in the future" (5M-2). Table 7 presents more examples from low, medium, and high-group participants' second interview responses, which demonstrates positive shifts in their confidence to teach science.

Table 7 Participants' confidence to teach science (at the beginning and end of the course)

Group	Participant	First interview	Second interview
Low	2L	I would *say either a 2 or a 1 [confidence level]* because having them [future students] ask me questions and *me not knowing the answers is one of my biggest fears*	I would say probably *like a 4*. Because *I am more confident now* and I believe that *I would be a better science teacher now* than I would have before because I have the ideas now
	4L	*Probably 1 or 2, I feel like at this point, I could not teach it*, I mean may be if I have a lesson plan or something like I could figure it out on my own but like I don't feel like I would be very much help…even like *if they are like asking questions I don't feel like I could answer a lot of them*	*Probably 4 or 5* if it was just the information that we learned in this class. Having all that I feel like I thoroughly learned it… *I feel like I could explain it, give examples* I could relate it back like when I was in physics, this is the experiment we did, more relate it back and remember specific examples *and I feel a lot more confident in teaching it*
Medium	2M	I would give *myself a 3*. I mean I can look up background knowledge and be confident in teaching it but I wouldn't like choose to. *I would not enjoy teaching science*	*Close to 4*. I think I can teach elementary physics from this course I think *I can definitely have confidence to teach the younger kids in elementary school*. This course in general, the information, I mean it was more like the basic information but *explained to you in a way that you can teach it to someone else*
	5M	I would probably say *around a 3*. I have taken a lot of science courses but when asked to questions by students, *my confidence is not as high as I want it to be* because I want to ensure that I give the correct answer	I think *4 would be a solid number* to go or align with. Now that I have gotten through the course, I am definitely a *lot more confident in my knowledge of these ideas that I can present to the students* in the future. I think I do have a fair amount of *confidence in being able to teach this to students in the future*
High	4H	I would probably say may be *like a 4*. I have the science knowledge…its just the ability to *how to teach it right now is not where it should be* I mean so I need to get more knowledge on *how to get things through to kids*	I will probably *say about a 4.5 or 5*. I know the material pretty well now. *I am very confident that I know the material well* and I can teach it. Like I feel that *I can take all the information that I have learned and turn into a lesson plan for the kids*
	6H	As of now *may be a 3*. I have a really basic understanding, I *don't have enough of an understanding that I would be confident getting up and talking about it*	*Like a 4.5 or 5*. I am a lot more confident in what I have been taught and *I am a lot more confident that I could teach it*. I mean the *experiments that we did* have kind of *made me more confident in different techniques to use to teach it*

Several participants credited their positive experiences with hands-on science learning for achieving new levels of confidence and that these experience provided them ideas for future science teaching. Moreover, the participants who had previously mentioned fear of not being able to answer to students' questions indicated that they felt confident in addressing students' questions in the future. For example, a medium group participant said, "I am definitely a lot more confident in the basic concepts of physics…I would be a very good science teacher just because I like to be hands-on with my students." She went on to talk about her future students and said, "I would be able to answer any questions that they have" (5M-2).

The expressions of positive shifts in confidence to influence future students' science learning were more evident in the high and medium group, and the participants from the low group did not link their personal gains in confidence to teach to their future students' potential learning gains. For example, in one instance a participant in the low group expressed confidence in her own understanding of a particular science idea but went on to express concern regarding her future students' understandings: "I only understand it to a certain extent for me to understand it, but I don't know if I can help someone else to totally understand it as well" (1L-2).

In summary, trends showed positive changes in most of the participants' science teacher self-images and confidence after participation in the course. While these positive trends support group participants' positive shifts in self-efficacy beliefs, a few participants from the low group expressed their discomfort with teaching science. The lack of content knowledge and low confidence seemed to interfere with some of the low-group participants' views of themselves as science teachers. These participants also seemed to be less comfortable with their abilities to influence student learning through their future science teaching.

Relationship Between Science Self-Efficacy and Science Conceptual Understanding

Pearson product–moment correlation coefficients (r) were calculated for self-efficacy (both PSTE and STOE) and science conceptual understanding. Results of this analysis revealed no statistically significant correlation between pre-PSTE and pre-Content and between pre-STOE and pre-Content scores (see Table 8). Similarly, no statistically significant correlations were found between post-PSTE and post-Content or between post-STOE and post-Content scores. Interestingly,

Table 8 Correlations between PSTE, STOE and content ($N = 51$)

	Pre	Post	Gains
Content			
PSTE			
Pearson correlation	.176	.183	.349
Sig. (two-tailed)	.217	.199	.012*
STOE			
Pearson correlation	−.124	.190	.001
Sig. (two tailed)	.386	.181	.994

* Correlation is significant at .05 level (two-tailed)

statistically significant correlations were found between gains in PSTE scores and gains in conceptual understanding ($r = .35$, $p \ll .05$); however, no significant correlation was found between gains in STOE scores and gains in conceptual understanding.

The patterns observed in the qualitative data also supported a positive relationship between science conceptual understandings and science self-efficacy beliefs. The links were evident in the ways in which participants expressed perceived preparedness in the science content and abilities to teach that content. As one participant said, "I think *I could definitely teach an awesome unit on how to light a bulb* because we spent so much time on it" (1M-2). The participants, particularly from the low group, who initially had expressed concerns regarding a lack of content knowledge explicitly stated that they had a better and a deeper understanding of science concepts taught in the course. Such improved science content understandings facilitated their gains in confidence for science teaching. As one participant from the low group said:

> *I feel confident on the content* that we learned in our physics class. Just the information that we learned in this class…having all that I feel like I will remember so *I feel like I could re-teach all of it* to other people as I thoroughly learned it. *I feel a lot more confident in teaching it*. (4L-2)

Discussion and Implications

Development of Science Self-Efficacy Beliefs

The primary goals for this study were to examine preservice elementary teachers' science self-efficacy beliefs during their participation in a specialized physics content course, how self-efficacy beliefs might change, and if/how these changes may relate to changes in preservice teachers' science conceptual understandings. The trends from STEBI-B results and participants' responses to interview questions strongly suggest positive changes in their science self-efficacy beliefs. The findings of this study regarding positive gains in self-efficacy beliefs on both scales (PSTE and STOE) are consistent with previous studies that explored teacher self-efficacy in the context of methods courses (Bautista, 2011; Bleicher & Lindgren, 2005; Cantrell, 2003; Palmer, 2006a, b) and science content courses (Bergman & Morphew, 2015; Narayan & Lamp, 2010). In this study, the practical significance was higher for PSTE (partial $\eta^2 = .656$) as compared to STOE (partial $\eta^2 = .178$). The higher effect in PSTE was also evident in the participants' discussions of themselves as future science teachers and confidence to teach science. The large effect in PSTE seems logical, as participants were engaged in learning science content first-hand and that increased science content understandings may have contributed toward positive perceptions of science and science teaching.

One logical explanation for the moderate effect in STOE as compared to PSTE could be that the participants had no formal classroom teaching experience and had yet to student teach. Therefore, asking preservice teachers to assess how their future students will respond to their science teaching (STOE) before their student teaching experience may be particularly difficult. Another reason for the moderate effect in STOE could be that the participants in this study had yet to take their science methods courses. The content course did not intend to focus explicitly on "methods" of teaching science but utilized effective pedagogical models for teaching science content. One potentially productive area of research would be to continue to investigate STOE once participants completed their science methods coursework. Possibilities for further research could also include studies that continue to explore factors that influence preservice teachers' outcome expectancy beliefs—looking into in-school factors (for example, school administration and support, collegial support, time and resources, classroom management, student behavior), and out-of-school factors (for example, family support, community) could prove beneficial. Such factors are not generally discussed in science content courses, but are explicitly addressed in methods coursework.

Researchers suggest that developing preservice teachers' science self-efficacy early on before they enter into their methods coursework is critical (Avery & Meyer, 2012; Hechter, 2011), and our findings indicate that this is possible through science content courses. An advantage of having high science self-efficacy beliefs is that these beliefs may support smooth transitioning into their science methods coursework and student teaching (Bautista, 2011; Gunning & Mensah, 2011). In this study, the participants felt confident in the science content learned in the course and felt comfortable teaching it. The results obtained are promising, considering that these preservice teachers are more likely to arrive in their science methods courses with increased levels of science self-efficacy beliefs. Such improved levels of confidence to teach science and perceptions of themselves as science teachers are more likely to translate into practice in their future science teaching endeavors.

The study has implications for preservice teacher education programs and future research. First, science content courses should be designed in ways that are consistent with ways preservice teachers are expected to teach. Science educators involved in designing such courses must include science experiences to make science learning relevant and realistic to students and for their future teaching. Our study adds to what has been a limited body of research and shows that specialized content courses designed for elementary science teachers can serve as appropriate contexts for learning science in ways that contribute to increases in preservice teachers' science self-efficacy beliefs (Knaggs & Sondergeld, 2015; Narayan & Lamp, 2010). These specialized content courses offer advantages over traditional content courses in that they provide opportunities to engage students in science learning with exposure to effective science teaching practices.

Second, we argue that continuous support and mentoring is needed throughout the preservice science teacher preparation program, especially for low efficacious students, to continue to develop their science self-efficacy beliefs. Not all preservice teachers have prior experiences that are positive, and many of them may not perceive themselves as science teachers (Knaggs & Sondergeld, 2015), as in the case of this study (low and medium group). Preservice teachers like those that were represented in our low and medium groups may have a greater need for inquiry-based science experiences to prepare them for future science teaching. Preservice teachers, especially those with low science self-efficacy, need ongoing encouragement to build positive perceptions of themselves as science teachers (Velthuis et al., 2014). Science educators should continue to make efforts to extend their support for preservice teachers throughout their teacher preparation.

Third, more research is needed to understand how self-efficacy beliefs can be supported in science courses and at other stages of teacher preparation programs. One area that deserves research attention involves looking holistically at teacher preparation programs to understand how levels of self-efficacy are maintained throughout preservice programs. Further, longitudinal studies would help to get a closer look at how gains in self-efficacy translate into classroom practices. Such longitudinal studies would also help improve the design of preservice courses for preparing a next generation of high-quality science teachers (Cakiroglu, Capa-Aydin, & Hoy, 2011).

Science Self-Efficacy and Science Conceptual Understanding

One body of the literature suggests that having access to science disciplinary knowledge, conceptualized as the number of science courses taken by preservice teachers, is critical to gain competence in teaching science (Hechter, 2011; Jarrett, 1999). Another body of the literature asserts that in-depth understanding of science content is necessary for developing confidence to teach science (Appleton, 2006; Bleicher & Lindgren, 2005; Jarrett, 1999). Therefore, there is reason to conjecture that science content knowledge and self-efficacy beliefs are linked (Bleicher & Lindgren, 2005). In contrast, data from this study showed no significant relationships between science conceptual understanding and science self-efficacy subscales (PSTE and STOE) on the pretest or posttests. However, one of the interesting findings of this study is that there was a significant relationship between the *gains* in personal science teaching efficacy beliefs (PSTE scale) and the *gains* in science conceptual understandings ($r = .35$). The correlation is moderate but statistically significant; therefore, it is highly likely that other factors contribute to developing positive self-efficacy. However, the relationship revealed here warrants additional attention.

The correlation results between the gains in the two constructs suggest a more complicated picture of the association between science conceptual understandings and science self-efficacy beliefs than suggested by previous research in this area. The findings suggest that there is not necessarily a relationship between science conceptual understanding and science self-efficacy beliefs in an absolute sense. However, there is a relationship between the process of learning science and the development of science self-efficacy beliefs. The qualitative data from participants' interviews also supported this trend: participants' explanations of their own experiences suggested that progress on science learning was linked to their development of PSTE beliefs. These findings are consistent with a viewpoint in the literature that mere exposure to subject matter knowledge, conceptualized by other research studies as the number of science courses taken, may not be a reliable predictor of preservice elementary teachers' confidence to teach science in their future classrooms (Hechter, 2011; Tosun, 2000).

Many preservice teachers arrive in college with limited science content knowledge, and this limitation affects their perceptions of themselves as science teachers (Yoon et al., 2006). College science training is crucial and can serve as a *platform* for supporting development of science self-efficacy beliefs. Recognizing that the process of development of deeper conceptual understanding and the process of increasing self-efficacy are interconnected, science educators must create new experiences situated in environments that foster development of science conceptual understanding and science self-efficacy beliefs.

Conclusions

A number of research studies have suggested that self-efficacy is influential to student learning (Knaggs & Sondergeld, 2015; Leonard et al., 2011). With regard to elementary science teaching, science teacher educators emphasize that preservice teachers' beliefs about science serve as a lens through which they view themselves as future science teachers. This study is unique in examining the changes in science self-efficacy beliefs among preservice elementary teachers who demonstrated varied initial levels of self-efficacy beliefs at the beginning of a specialized science content course. The results provided evidence that preservice teachers enrolled in the specialized content course experienced positive changes in their science self-efficacy beliefs, and that the development of self-efficacy beliefs and development of science conceptual understanding are interrelated. With regard to these findings, the study highlights the importance of designing specialized content courses for improving preservice science content training while demonstrating teaching approaches that could be applicable in their future classrooms.

References

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York, NY: Oxford University Press.

Appleton, K. (2006). Science pedagogical content knowledge and elementary school teachers. In K. Appleton (Ed.), *Elementary science teacher education: International perspectives on contemporary issues and practice* (pp. 31–54). Mahwah, NJ: Erlbaum.

Appleton, K., & Kindt, I. (1999). Why teach primary science? Influences on beginning teachers' practices. *International Journal of Science Education, 21*, 155–168.

Appleton, K., & Kindt, I. (2002). Beginning elementary teachers' development as teachers of science. *Journal of Science Teacher Education, 13*, 43–61.

Avery, L. M., & Meyer, D. Z. (2012). Teaching science as science is practiced: Opportunities and limits for enhancing preservice elementary teachers' self-efficacy for science and science teaching. *School Science and Mathematics, 112*, 395–409.

Baldwin, K. A. (2014). The science teaching self-efficacy of prospective elementary education majors enrolled in introductory geology lab sections. *School Science and Mathematics, 114*, 206–213.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191–215.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist, 37*, 122–147.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: Freeman.

Bandura, A., & Wood, R. E. (1989). Effect of perceived controllability and performance standards on self-regulation of complex decision making. *Journal of Personality and Social Psychology, 56*(5), 805–814.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weiss, A. M. (2013). *Report of the 2012 national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research Inc.

Bautista, N. U. (2011). Investigating the use of vicarious and mastery experiences in influencing early childhood education majors' self-efficacy beliefs. *Journal of Science Teacher Education, 22*, 333–349.

Bergman, D. J., & Morphew, J. (2015). Effects of a science content course on elementary preservice teachers' self-efficacy of teaching science. *Journal of College Science Teaching, 44*, 73–81.

Bleicher, R. E. (2004). Revisiting the STEBI-B. Measuring self-efficacy in preservice elementary teachers. *School Science and Mathematics, 104*, 383–391.

Bleicher, R. E., & Lindgren, J. (2005). Success in science learning and preservice science teaching self-efficacy. *Journal of Science Teacher Education, 16*, 205–225.

Brand, B. R., & Wilkins, J. L. M. (2007). Using self-efficacy as a construct for evaluating science and mathematics methods course. *Journal of Science Teacher Education, 18*, 297–317.

Bybee, R. W. (1997). *Achieving science literacy: From purposes to practices*. Portsmouth, NH: Heinemann.

Cakiroglu, J., Capa-Aydin, Y., & Hoy, A. W. (2012). Science teaching efficacy beliefs. In B. J. Fraser, K. Tobin & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 449–461). Netherlands: Springer.

Cantrell, P. (2003). Traditional vs. retrospective pretests for measuring science teaching efficacy beliefs in preservice teachers. *School Science and Mathematics, 103*, 177–185.

Cantrell, P., Young, S., & Moore, A. (2003). Factors affecting science teaching efficacy of preservice elementary teachers. *Journal of Science Teacher Education, 14*, 177–192.

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practice, 8*, 293–307.

Chandrasekhar, M., & Kosztin, D. (2012). *Exploring physics: Electricity and magnetism and force and motion workbook*. Columbia, MO: Department of Physics and Astronomy, University of Missouri.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Erlbaum.

Corasaro, W. (1981). Entering the child's world: Research strategies for field entry and data collection in a pre-school setting. In J. Green & C. Wallach (Eds.), *Ethnography and language in educational settings*. Norwood, NJ: Ablex.

Corsaro, W. A. (1985). *Friendship and peer culture in the early years*. Norwood, NJ: Ablex.

Crowther, D. T., & Bonnstetter, R. J. (1997). *Science experiences and attitudes of elementary education majors as they experience Biology 295: A multiple case study and substantive theory*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. Oak Brook, IL.

Dembo, M. H., & Gibson, S. (1985). Teachers' sense of efficacy: An important factor in school improvement. *The Elementary School Journal, 86*, 173–184.

Engelhardt, P. V., & Beichner, R. J. (2004). Students' understanding of direct current resistive electrical circuits. *American Journal of Physics, 72*, 98–115.

Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teaching belief instrument: A preservice elementary scale. *School Science and Mathematics, 90*, 694–706.

Field, A. (2009). *Discovering statistics using SPSS*. Thousand Oaks, CA: Sage.

Gist, M. E., & Mitchell, T. R. (1992). Self-efficacy: A theoretical analysis of its determinants and malleability. *Academy of Management Review, 17*, 183–211.

Gunning, A. M., & Mensah, F. M. (2011). Preservice elementary teachers' development of self-efficacy and confidence to teach science: A case study. *Journal of Science Teacher Education, 22*, 171–185.

Guskey, T. R., & Passaro, P. D. (1994). Teacher efficacy: A study of construct dimensions. *American Educational Research Journal, 31*, 627–643.

Hechter, R. P. (2011). Changes in preservice elementary teacher's personal science teaching efficacy and science teaching outcome expectancies: The influence of context. *Journal of Science Teacher Education, 22*, 187–202.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher, 30*(3), 141–158.

Jarrett, O. (1999). Science interest and confidence among preservice elementary teachers. *Journal of Elementary Science Education, 11*, 47–57.

Kazempour, M., & Sadler, T. D. (2015). Pre-service teachers' beliefs, attitudes, and self-efficacy: A multi-case study. *Teaching Education, 26*, 247–271. doi:10.1080/10476210.2014.996743

Knaggs, C. M., & Sondergeld, T. A. (2015). Science as a learner and as a teacher: Measuring science self-efficacy of elementary preservice teachers. *School Science and Mathematics, 115*, 117–128.

Leonard, J., Barnes-Johnson, J., Dantley, S. J., & Kimber, C. (2011). Teaching science inquiry in urban contexts: The role of elementary preservice teachers' beliefs. *Urban Review, 43*, 124–150.

Levine, T. R., & Hullett, C. R. (2002). Eta squared, partial eta squared and misreporting of effect size in communication research. *Human Communication Research, 28*, 612–625.

Morse, J. M., & Niehaus, L. (2009). *Mixed method design: Principles and procedures*. Walnut Creek, CA: Left Coast Pr.

Mulholland, J., & Wallace, J. (1996). Breaking the cycle: Preparing elementary teachers to teach science. *Journal of Elementary Science Education, 8*(1), 17–38.

Mulholland, J., & Wallace, J. (2001). Teacher induction and elementary science teaching: Enhancing self-efficacy. *Teacher and Teacher Education, 17*, 243–261.

Narayan, R., & Lamp, D. (2010). "Me? Teach science?" Exploring EC-4 preservice teachers' self-efficacy in an inquiry-based constructivist physics classroom. *Educational Research and Reviews, 5*(12), 748–757.

National Research Council (NRC). (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council (NRC). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academic Press.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*, 328–371.

Next Generation Science Standards (NGSS) Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: National Academics Press.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory*. New York, NY: McGraw-Hill.

O'Brien, R. G., & Kaiser, M. K. (1985). MANOVA method for analyzing repeated measures designs: An extensive primer. *Psychological Bulletin, 97*(2), 316.

Osterlind, S. J. (2006). *Modern measurement: Theory, principles, and applications of mental appraisal*. Upper Saddle River, NJ: Pearson/Merrill Prentice Hall.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*, 307–333.

Palmer, D. (2006a). Durability of changes in self-efficacy of preservice primary teachers. *International Journal of Science Education, 28*, 655–671.

Palmer, D. (2006b). Sources of self-efficacy in a science methods course for primary teacher education students. *Research in Science Education, 36*, 337–353.

Ramey-Gassert, L., & Shroyer, M. G. (1992). Enhancing science teaching self-efficacy in preservice elementary teachers. *Journal of Elementary Science Education, 4*(1), 26–34.

Ramey-Gassert, L., Shroyer, M. G., & Staver, J. R. (1996). A qualitative study of factors influencing science teaching self-efficacy of elementary level teachers. *Science Education, 80*, 283–315.

Rice, D. C., & Roychoudhury, A. (2003). Preparing more confident preservice elementary science teachers: One elementary science methods teacher's self-study. *Journal of Science Teacher Education, 14*, 97–126.

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74*, 625–637.

Settlage, J. (2000). Understanding the learning cycle: Influences on abilities to embrace the approach by preservice elementary school teachers. *Science Education, 84*, 43–50.

Strauss, A., & Corbin, J. (1988). *Basics of qualitative research: Techniques and procedures of developing grounded theory*. Thousand Oaks, CA: Sage.

Tashakkori, A., & Teddlie, C. (2010). *Sage Handbook of mixed methods in social and behavioral research*. Thousand Oaks, CA: Sage.

Tosun, T. (2000). The impact of prior science course experience and achievement on the science teaching self-efficacy of preservice elementary teachers. *Journal of Elementary Science Education, 12*(2), 21–31.

Trigstad, P. J., Smith, P. S., Banilower, E. R., & Nelson, M. M. (2013). *The status of elementary science education: Are we ready for the Next Generation Science Standards?* Retrieved from http://www.horizonresearch.com/2012nssme/wpccontent/uploads/2013/06/The-Status-of-Elementary-Science-Education_paper.pdf

Tschannen-Moran, M., Hoy, A. W., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research, 68*, 202–248.

Velthuis, C., Fisser, P., & Pieters, J. (2014). Teacher training and pre-service primary teachers' self-efficacy for science teaching. *Journal of Science Teacher Education, 25*, 445–464.

Watters, J. J., & Ginns, I. S. (2000). Developing motivation to teach elementary science: Effect of collaborative and authentic learning practices in preservice education. *Journal of Science Teacher Education, 11*, 301–321.

Yoon, S., Pedretti, E., Pedretti, L., Hewitt, J., Perris, K., & Van Oostveen, R. (2006). Exploring the use of cases and case methods in influencing elementary preservice science teachers' self-efficacy beliefs. *Journal of Science Teacher Education, 17*, 15–35.