DEVELOPMENT OF PRESERVICE ELEMENTARY TEACHERS’ SCIENCE SELF-EFFICACY BELIEFS AND ITS RELATION TO SCIENCE CONCEPTUAL UNDERSTANDING

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by
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DEDICATION

To the Almighty Lord: Mother of Knowledge Saraswati Maa – for showing the light

To my son Rayan for all your smiles and giggles that put all my worries away

To my husband Sunil for all the love, care and support throughout this journey

To my parents for always believing in me and showing me the path that leads to light
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ABSTRACT

Self-efficacy beliefs that relate to teachers’ motivation and performance have been an important area of concern for preservice teacher education. This study used a mixed-methods approach to investigate the changes in preservice elementary teachers’ science self-efficacy beliefs and the factors associated in a specialized elementary physics content course. In addition, the study is one of few to investigate the relationship between the changes in science self-efficacy beliefs and changes in physical science conceptual understanding. Participants included fifty-one preservice elementary teachers enrolled in two term of the physical science content course.

Data collection and analysis procedures included both qualitative and quantitative measures. Data collection included implementation of Science Teaching Efficacy Belief Instrument-B (STEBI-B) (Bleichner, 2004) and Physical Science Concept Test as pre- and post-test, two semi-structured interviews with 18 participants (nine each semester), classroom observations and artifacts. A pre-post, repeated measures multivariate analysis of variance (MANOVA) 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 on both scales of STEBI-B - personal science teaching beliefs and outcome expectancy beliefs. Additionally, a positive moderate relationship between science conceptual understandings and personal science teaching efficacy beliefs was found.

Post-hoc analysis of the STEBI-B data was used to select 18 participants for interviews. The participants belonged to each group representing the low, medium and high initial levels of self-efficacy beliefs. Participants’ responses indicated positive shifts
in their science teacher self-image and confidence to teach science in future. Four
categories that represented the course-related factors contributing towards science self-
efficacy beliefs included: (1) enhanced science conceptual understandings, (2) active
learning experiences, (3) teaching strategies, and (4) instructor as a role-model. Findings
suggest that despite of the nature of prior science experiences preservice elementary
teachers previously had, an exposure to a course that integrates relevant science content
along with modeled instructional strategies can positively impact science self-efficacy
beliefs. While some course elements such as active learning experiences and teaching
models seemed to impact all groups positively, the low group participants were
particularly influenced by the multiple representations of the content and the course
instructor as a role model. These findings have important implications for preservice
science teacher preparation programs.
CHAPTER 1
THE PROBLEM

Introduction

“Teachers of science will be the representatives of the science community in their classrooms, and they form much of their image of science through the science courses that they take in college.” (National Science Education Standards, National Research Council (NRC), 1996, p. 61)

Science education reform strives to ensure that all preservice science teachers demonstrate high quality science instruction in their future teaching. The new approach to K-12 science education suggested by the Next Generation Science Standards (NGSS Lead States, 2013) and its guiding framework (NRC, 2011) emphasize that all learners should develop a strong foundation of science content focusing on disciplinary core ideas, scientific practices and crosscutting concepts. In order to meet these demands, preservice teachers must undergo similar experiences of learning science content in ways they are expected to teach in future. Science educators who espouse this position argue that teachers teach the way they are trained (Anderson, Smith & Peasley, 2000), thus fulfillment of these expectations requires rigorous training of preservice teachers in their teacher preparation programs.

A number of policy documents (American Association for the Advancement of Science (AAAS), 1993; NRC, 1996; NRC, 2012) recommend improvement in K-12 science instruction through Standards outlined in these documents. The central goal of achieving high quality teaching standards in K-12 classroom require major reforms in teacher education programs (National Science Foundation, 1996). The National Science Education Standards emphasize that “Current reform effort in science education requires a substantial change in teaching practices of how science is being taught at all levels”
While other professional agencies continued to provide guidelines to meet the demands of ever-changing, complex and diverse society, the No Child Left Behind Act (2001) mandate calls for highly qualified elementary science teachers. The document defines “highly qualified teacher (HQT) as one holding a bachelor’s degree in the core academic area such as math, science, English language arts etc. and demonstrates subject matter competence (content knowledge) in the core subject(s) she/he teaches” (No Child Left Behind Act, 2001, p. 1). As a result, teacher educators are under tremendous pressure to prepare a pool of high-quality science teachers capable of meeting the needs and demands of their diverse classrooms.

Despite the calls for reforms to be made in preservice programs, research highlights concerns regarding effective preservice science education (Appleton, 2003; Howes, 2002; Mulholland & Wallace, 2001). Additionally, a common theme across research on elementary science education suggests that elementary teachers are reluctant to teach science (Abell & Roth, 1992; Appleton, 2003; Gess-Newsome, 1999). In general, research studies attribute three reasons for such avoidance of science in elementary classrooms: (1) a lack of sufficient background (Dobey & Schafer, 1984; McDermott, 1990; Schoeneberger & Russell, 1986), (2) a lack of confidence to teach it (Appleton, 2003; Crowther & Bonnsteller, 1997), and (3) a traditional structure of undergraduate science courses (Crowther & Bonnsteller, 1997; McDermott, Shaffer & Constantinou, 2000).

The reports from various national surveys also reflect concerns regarding the quality of elementary science instruction. The report from the 1985-1986 National survey of elementary teachers specifies that only 15% were confident enough to teach physical
science (Weiss, 1987). This percentage dropped to 14% in the report from the 2000 National survey (Fulp, 2002). Survey results from the 2000 National Survey of Science and Mathematics Education revealed that less than 18% of the elementary teachers felt qualified to teach physical science, and only 24% for teaching any science (Weiss, Banilower, McMahon & Smith, 2001). Despite the calls and systemic reform initiatives to improve science teaching in elementary classrooms (AAAS, 1993; No Child Left Behind, 2000; NRC, 1996; van Driel, Beijaard & Verloop, 2001); only 17% of the elementary teachers felt prepared to teach physical science and 33% for teaching any science (Banilower et al. 2013; Trygstad et al., 2013). Furthermore, both anecdotal evidence as well as research suggest that among all the sciences to be taught in elementary classrooms, physical science is neglected the most (Atwater, Gardner, & Kight, 1991; Darling-Hammond & Hudson, 1990; McDermott, 1990).

Reform recommendations for preservice model programs include: specialized content courses (NRC, 1996) to enhance science content knowledge of preservice elementary science teachers (DeTure, Gregory, & Ramsey, 1990; Duran, McArthur, & Van Hook, 2004; Hall, 1992), especially physical science (McDermott, 1990, McLoughlin & Dana, 1999), promotion of active learning through inquiry-based practices (Duran, et al., 2004; Messina, DeWalter, & Stetzer, 2004; NRC, 1996), improve preservice teachers’ confidence (Dresser, 1988; McLoughlin & Dana, 1999) as well as beliefs and attitudes regarding science teaching (Hall, 1992; Stephans, McClurg, & Beiswenger, 1995; Friedrichsen, 2001), and improve science self-efficacy beliefs regarding science teaching and learning (Cantrell, Young, & Moore, 2003; Lakshmanan,

While much research has been conducted in each of the aforementioned areas, this study focuses on two major areas: (1) science self-efficacy beliefs and (2) science conceptual understandings with regard to preservice elementary teacher education. Both science self-efficacy beliefs and science content knowledge influence preservice teachers’ future teaching performances. This study was designed to investigate preservice elementary teachers’ science self-efficacy beliefs as well as to provide a logical understanding of the relationship between their science conceptual understanding and science self-efficacy beliefs. This study builds on Bandura’s (1977) definition of self-efficacy as “beliefs,” as discussed in the following section.

**Operational Definition of Important Terms in the Study**

The self-efficacy construct, derived from Social Cognitive Theory, was first conceptualized by Bandura (1977) as a judgment of individuals’ own capabilities to perform necessary actions that they believe could lead to desired results. Bandura proposed that self-efficacy consists of two distinct dimensions: personal science teaching efficacy beliefs (PSTE) relates to individual’s ability to execute actions required to achieve desired goals, and science teaching outcome expectancy (STOE) relates to individuals’ judgment of the anticipated results their performances may produce. For the purposes of this study, the term “science self-efficacy” refers to (1) the beliefs that shape teachers’ abilities to make decisions regarding classroom science teaching and (2) beliefs that their science teaching will produce their desired student learning outcomes (Bandura, 1977; 1982; Tschannen-Moran, Hoy, & Hoy, 1998).
In this investigation, the definition of “science content knowledge” comes from National Science Education Standards (NRC, 1996, 2012). It is defined as a scientific knowledge-base consisting of facts, theories, concepts and principles (NRC, 1996) as well as “integration of the knowledge of scientific explanations” (NRC, 2012). In the context of this study, “specialized content course” refers to science content courses specifically designed for preservice elementary teachers who learn to integrate understanding of science concepts with the pedagogical models as advocated by the national reform efforts (Crowther & Bonnstetter, 1997).

This study investigated the changes in science self-efficacy beliefs of preservice elementary science teachers in the context of a specialized physics content course. Also, the study examined the relationship between preservice elementary teachers’ science self-efficacy and the conceptual understanding of physics concerning topics aligned with elementary grade-level science such as electricity and magnetism and force and motion. The following sections identify the key research issues relevant to this exploration (the relevance of science self-efficacy beliefs in preservice teacher preparation and relationship between teachers’ science content knowledge and science self-efficacy beliefs). Additionally, Chapter I includes a detailed discussion of specialized content courses and the rationale for using them as a context for the investigation of the research issues. The chapter includes a theoretical framework used for the study, the problem statement on which the study is based, the specific research questions and sub-questions investigated along with a rationale for them. The chapter concludes with the significance of the study as well as a summary paragraph.
Research Issues

Teacher Self-Efficacy and Preservice Science Teacher Preparation

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). With regard to the teaching profession, several researchers relate these belief systems to the development of positive attitudes as well as to teachers’ behavior (Nespor, 1987; Pajares, 1992). This interrelationship among teachers’ beliefs, attitudes and teachers’ classroom behavior has been the topic of great interest in the science education research community. These beliefs have been highly influential in teachers’ classroom practices (Pajares, 1992), and deserve more investigation.

With Bandura’s claims that self-efficacy beliefs are the strongest predictors of motivation and performance (Bandura, 1986), there is consensus among researchers involved with preservice teacher education that the beliefs held by preservice elementary teachers are carried along their way to future classrooms (Enochs & Riggs, 1990; Ramey-Gassert & Schroyer, 1992). For example, Appleton and Kindt’s (2002) study confirmed that beginning teachers with low confidence preferred to use reading and writing strategies such as worksheets over hands-on activities to teach science. Studies on teacher behavior suggest that teachers with low science self-efficacy prefer authoritarian approaches to teaching (Bandura, 1997; Palmer, 2006), which hinder effective science instruction. Additionally, low efficacious teachers tend to rely on books and prescribed material, which limit students’ thinking and creativity to understand science concepts (Ramey-Gassert & Schroyer, 1992).
The present descriptions of elementary science education demonstrate that classroom teachers lack knowledge and skill to teach science through reform-based practices (Tilgner, 1990), which brings serious concerns on how these classroom elementary teachers are trained during their preservice programs. A number of studies document that preservice teachers are often subjected to formal science coursework typically based on ineffective science practices, consequently creating their negative attitudes and beliefs towards science teaching (Mulholand & Wallace, 1996; Rice & Roychoudhury, 2003). Most of preservice science coursework consists of traditional lecture, reading books and completing worksheets that promote rote memorization (Rice & Roychoudhury, 2003) and leads to poor science knowledge (Stevens & Wenner, 1996; Trundle, Atwood & Christopher, 2002). These negative experiences along with inadequate science content preparation damage the confidence-level of preservice teachers (Jarrett, 1999; Mulholand & Wallace, 2001). Furthermore, these experiences either inhibit future science teaching or influence prospective teachers to an extent that they tend to avoid teaching elementary science completely (Appleton & Kindt, 1999).

Although some researchers argue that beliefs about teaching and learning are set firmly by the time prospective elementary teachers enter preservice programs and are difficult to amend (Kagan, 1992; Pajaras, 1992), others suggest that effective science experiences may help to address some of the concerns and apprehensions about their ability to teach science (Gencer & Cakiroglu, 2007; Mulholland & Wallace, 2001). Several researchers argue that designing high quality science coursework has the potential to shape preservice teachers’ pre-existing beliefs (Mulholland and Wallace, 2001) and to enhance both personal self-efficacy beliefs as well as beliefs in their actions.
leading to successful outcomes (Cantrell et al., 2003). One hypothesis is that the more positive the impact on preservice teachers’ science self-efficacy beliefs throughout their coursework, the more they are likely to positively influence the student achievement in their future classrooms.

Because self-efficacy is influential to student learning (Bandura, 1997), studying teachers’ beliefs have important implications for research in curriculum, instruction and classroom practices. The study was designed to provide a greater understanding of how preservice science experiences play a key role in shaping science self-efficacy beliefs that influence future teaching and provide insights for improved preservice elementary teacher preparation. Because teacher self-efficacy is one of the major determinants of effective future science teaching, this study aimed to investigate how preservice teachers’ science self-efficacy beliefs improved during their exposure to a particular physical science content course.

**Teacher Self-efficacy and Science Content Knowledge**

While there has been an emphasis on preparing elementary teachers in a way that they feel confident in the science content knowledge as outlined by *National Science Education Standards* (NRC, 1996), science content provided to preservice teachers in terms of the breadth and the depth in science coursework has raised concerns on how well-prepared these teachers feel to teach science. The *Standards* (NRC, 1996; 2012) state that science content preparation should enable preservice teachers to develop a strong foundation of science content in order to fulfill the demands of diverse learners in their future classrooms. Not only are elementary teachers required to meet state science curriculum standards, but they are expected to facilitate scientific understanding through
inquiry-based learning processes. In order to meet these demands, preservice teachers need similar experiences of learning science content in the way they are expected to teach in future. Also, there is a general consensus that a lack of such background knowledge in science often leads to the development of anxiety and fear towards science, affecting self-efficacy and the confidence to teach it (Appleton, 2006; Tilgner, 1990).

With science content knowledge as one of the limiting factors for effective science instruction, several attempts have been made to understand the linkage between science content knowledge, attitudes, and beliefs held by preservice teachers. Related literature posits that integrated science content and methods courses that blend science content and pedagogy together effectively enhance self-efficacy beliefs (Bleicher & Lindgren, 2005; Tosun, 2000); however, the effect of science content knowledge by itself on science self-efficacy beliefs is debatable (Tosun, 2000). Moreover, while research has consistently shown that preservice science methods courses build on inquiry-based learning environments positively influence attitudes and confidence (Friedrichsen, 2001; Hall, 1992; Reisetter, Bruning and Veomett, 1998), little is known about the relationship between teachers’ science conceptual understanding and self-efficacy beliefs.

A few studies have been conducted related to the impact of science content courses on changes in preservice teachers’ attitudes or self-efficacy (Ginns, Tulip, Watters & Lucas, 1995; Morrell & Carroll, 2003; Watters & Ginns, 1995). Findings from these studies provide recommendations for effectiveness of content courses rather than providing any clear picture of the relationship between science conceptual understanding and self-efficacy beliefs. A handful of studies that are directed toward understanding the role that content knowledge may play in affecting preservice science self-efficacy beliefs
provide conflicting results, further providing impetus for conducting this present study. For instance, a few studies show that the quality of high school science experiences along with the number of science courses taken in preservice teacher preparation programs enhance their confidence levels (Jarrett, 1999; Moore & Watson 1999); others claim that additional science content courses may not necessarily have contributed towards science conceptual understanding (Wenner, 1993, 1995).

Only two studies have attempted to directly explore the correlation between the science conceptual understanding and science self-efficacy beliefs, but they revealed contrary results. While findings from the study conducted by Schoon & Boone (1998) revealed that the preservice teachers’ scores on a science test significantly correlated with both areas of science self-efficacy beliefs, results from study conducted by Bleicher & Lindgren (2005) revealed that conceptual understanding correlates with personal science self-efficacy but not with science teaching outcome expectancy beliefs. Together, these studies do not demonstrate a consistent relationship between changes in science conceptual understanding and changes in science self-efficacy beliefs, which are important issues for teacher preparation.

This study examined the relationship between changes in preservice teachers’ physical science conceptual understanding and changes in science self-efficacy beliefs in the context of a physical science content course. Over the years science educators have argued that increases in scientific knowledge bases subsequently influence self-efficacy beliefs. The study attempted to explore this contention to illustrate the role that science content knowledge plays in influencing self-efficacy beliefs.
Specialized Content Courses as Authentic Contexts for Exploration

In the past few decades, teacher educators have realized that traditional science content courses have failed to promote preservice teachers’ understanding of science and their confidence to teach science in the future (McLoughlin & Dana, 1999; Watters & Ginns, 2000). Researchers’ suggestions include improving preservice science content training through specialized science course work closely aligned with the elementary classroom curricula (McLoughlin & Dana, 1999; Morrell & Carroll, 2003). Additionally, such courses have been designed to incorporate inquiry and constructivist views on learning, provide explicit connections to the real world, and to provide opportunities to observe reform-based pedagogical models of teaching science (Lee & Krapfl, 2002; McLoughlin & Dana, 1999). Furthermore, the purpose of creating such courses were two-fold: (a) to stimulate learning by adopting ‘less is more’ approach and (b) to build on elementary science teaching self-efficacy beliefs necessary to teach effectively (Boone & Gabel, 1998; Dresser, 1988; McDermott, 1974; McLoughlin & Dana, 1999).

This literature documents several attempts made to re-design science content courses in all disciplines; however, much attention has been directed toward implementing specialized physical science content courses. Specifically, the literature provides ample evidence that traditional physics courses taken by education majors fail to provide the “type of preparation required for teaching physics” effectively (McDermott, Shaffer & Constantinou, 2000, p. 411). Recent studies on specialized content courses provide empirical evidence indicating the effectiveness of specialized content courses, the impact of such innovative courses on students’ perceptions, student achievement, student retention, self-efficacy beliefs, confidence and attitudes towards science
(Friedrichsen, 2001; McLoughlin & Dana, 1999; Trundle et al., 2007). Of particular interest for the present study are those empirical research studies that specifically investigate the impact of specialized content courses on preservice teachers’ science content knowledge, self-efficacy beliefs and confidence.

Two research studies were found that specifically reported that experiences in specialized content course enhanced preservice teachers’ confidence in science (Friedrichsen, 2001; Lee & Krapfl, 2002). The purpose of these studies was to assess/evaluate the newly-designed content courses in terms of being effective to bring sound conceptual understanding of science concepts as well as to build on confidence levels. However, neither of these studies explored changes in conceptual understanding or changes in self-efficacy beliefs in these contexts. Additionally, both studies utilized qualitative measures for analyzing participants’ claims in interviews about the impact of innovative course on their perceptions of being prepared to teach in future. Other research studies have also relied only on participants’ interviews to explore their perceptions regarding these contexts (Doster et al., 1997; Duran et al., 2004; McLoughlin & Dana, 1999).

The interrelationship between content knowledge and self-efficacy beliefs has been suggested in literature but has not been systematically explored in the context of specialized content courses. That being the case, due to the professional context in which science content knowledge is gained along with overt experiences with teaching models; a specialized content course serves as an appropriate research setting for this study. The purpose of this study was to investigate the relationship between preservice teachers’
science conceptual understanding and self-efficacy beliefs before and after taking a specialized physical science content course.

The focus of this study is illustrated in Figure 1. The specialized content course, which is the research context for the study, has been designed to fulfill two aims: (1) to enhance preservice teachers’ science content expertise and (2) modeling appropriate instructional strategies by presenting the content in the context of pedagogy. Although, science content knowledge is a vast domain that consists of subdomains such as physical science, life sciences, and Earth sciences and so on, for the purposes of this study preservice teachers’ physical science content knowledge was investigated. Along with subject matter knowledge and pedagogical skills, it is expected that the course is able to bring desired changes in prospective teachers’ science self-efficacy beliefs as they view themselves as future science teachers. Of particular interest to this present study was whether there is an interrelationship between changes in conceptual understanding of physics and science self-efficacy on both scales, PSTE and STOE. The target of the present investigation is highlighted by boxed area in the figure 1.

**Theoretical Framework**

**Social Cognitive Theory**

Social cognitive theory postulates that human functioning is determined by the interaction of three factors: a) personal factors such as beliefs, b) behavior, and c) environmental influences (Bandura, 1986). The theory offers a rich blend of both behavioristic and cognitive theories of learning, which emphasize learning as a product of interplay between cognitive, behavioral and contextual factors. This model of three
interrelated factors that influence human behavior is called triadic reciprocal causation (Bandura, 1977).

Bandura directed this theory to understand cognitive processes and suggested that learning influenced by the relationship between the three variables: personal, behavior, environmental. This relationship was called as ‘reciprocal determinism’ (Bandura, 1978). This is further explained through the links between each of the influential factors. For instance the link between personal and behavior factors suggests that individual’s beliefs, self-perceptions, and thought process influences their behavior. Applying the theory to teacher education, 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 (Bandura, 1989).

The second link between personal and environmental factors suggests that the beliefs and expectations as well as cognitive competencies could be shaped by social influences. In educational setting, modeling instruction, social persuasion and positive feedback will produce desired changes in learners’ beliefs about themselves as well as enhance their outcome expectations (Bandura, 1989). The final relationship in the triad provides relationship between behavior and environmental factors which suggest that behavior is shaped by the environmental factors and vice-versa as these links are bi-directional and not unidirectional. Applying to preservice teacher education, for instance, student-centered classrooms help increase students’ motivation to put all effort in learning how to teach. Similarly, constructive feedback provided by teacher motivates students to achieve their learning goals.
Self-efficacy-byproduct of Social Cognitive Theory

Derived from Social Cognitive theory, self-efficacy has emerged as an influential construct suggesting that human behavior and functioning is affected by the beliefs people hold. These beliefs have a tendency to change while individuals interact with the environment in which they function (Bandura, 1993).

Self-efficacy beliefs play a major role in determining teachers’ science teaching practices that include the choice of instructional activities, organization of science lessons, and their preparation to handle challenging situations (Bandura, 1997). Applied to elementary science teaching, researchers have suggested that highly efficacious teachers are more successful as science teachers (Appleton & Kindt, 2002), willing to take challenges teaching science (Ramey-Gassert, Shroyer & Staver, 1996), and are committed to teaching science (Riggs & Enochs, 1990). Additionally, teachers having high senses of self-efficacy are more likely to incorporate inquiry-based practices to their teaching, thus making extensive efforts to create learner-centered environments in their science classrooms (Watters & Ginns, 1990).

Self-efficacy beliefs are situation, context and subject-matter specific (Bandura, 1997, Tschannen-Moran et al., 1998). This suggests that the self-efficacy beliefs that elementary teachers may hold for subjects other than science may have little effect on their science teaching efficacy beliefs. Science teaching demands a great deal of effort and time for elementary teachers to put into designing inquiry-based lessons as opposed to using strategies based on reading and writing (Appleton & Kindt, 1999). High self-efficacy helps teachers to find a fine balance between their own roles as science teachers in elementary classrooms and them being confident that their students are learning.
This research study is shaped by Social Cognitive Theory proposed by Bandura (1977) derived from the social learning perspective and focusses on determining preservice teachers’ self-efficacy beliefs, how they change, and what factors cause these beliefs to change within the context of specialized physics content course. The specialized content course is a classroom framed in social constructivist perspective that offers favorable environment that could potentially shape self-efficacy beliefs. The framework of social cognitive theory is well suited for the study as it helps to understand the process of learning in the educational setting. The framework of social cognitive theory served as a guiding lens to understand preservice elementary teachers’ experiences within the science content course and their perceptions about science and science teaching, how their science self-efficacy beliefs are shaped through the interaction between personal, behavior and environmental factors within the context of the course.

**Problem Statement**

Science education reform strives to ensure that all preservice science teachers demonstrate high quality science instruction in their future teaching. Not only are elementary science teachers expected to teach the way described by the *National Science Education Standards* (1996, 2012) but they are also to cover the science content aligned with the curriculum standards. Many science educators argue that teachers tend to teach the way they are trained (Anderson, Smith & Peasley, 2000), thus science educators are need to ensure that preservice teachers are trained in their teacher preparation programs in ways that ensure effective future science teaching. Despite the calls for reforms to be made in teacher education programs, numerous research studies have pointed out that
preservice teachers lack adequate preparation as well as the confidence to teach science (Appleton, 2006; Ramey-Gassert & Schroyer, 1992; Tilgner, 1990).

Because self-efficacy is influential to student learning (Bandura, 1997), studying teachers’ beliefs have implications for research in curriculum, instruction and classroom practices. Science self-efficacy beliefs are a particularly important issue in science education; the idea provided one rationale of this study. The study was designed to provide a greater understanding of how preservice science experiences play a key role in shaping science self-efficacy beliefs that influence future teaching and to provide insights for improved preservice elementary teacher preparation.

In the science teaching context, researchers have identified self-efficacy as an influential construct (Enochs & Riggs, 1990). Literature concludes that teachers with inadequate science background tend to have low science teaching self-efficacy beliefs (Rubeck & Enoch, 1991). Although research studies have proposed several factors that contribute towards science self-efficacy beliefs, science content knowledge is prominent among them. However, there is lack of empirically-based research to provide clear evidence of interrelationships between science conceptual understanding and science self-efficacy beliefs. Furthermore, investigations have yet to be conducted in settings, such as specialized content courses, where the primary aim is to build on preservice teachers’ confidence by teaching the science content relevant to their future teaching. This study aimed to provide empirical evidence to understand some of these contentions. The findings of this study provide a deeper understanding of the relationships between conceptual understanding and science efficacy beliefs, two major determinants for successful science teaching.
Research Questions

Question 1

How do preservice elementary teachers’ science self-efficacy beliefs (personal science teaching self-efficacy-PSTE beliefs and science teaching outcome expectancy-STOE) change during a specialized physics content course?

Question 1a

Is there a significant change in science self-efficacy (PSTE and STOE) beliefs of preservice elementary teachers participating in the specialized physics content course?

Question 1b

What factors associated with the specialized physics content course contribute to changes in preservice elementary teachers’ science self-efficacy (PSTE and STOE) beliefs?

Rationale

Literature on self-efficacy beliefs emphasize that preservice teachers’ self-efficacy beliefs can be shaped through effective science preparation programs (Gunning & Mensah, 2011). Since science content courses are integral part of teacher training, it is reasonable to assume that experiences within these courses can impact science self-efficacy beliefs. A considerable amount of research studies on self-efficacy have been conducted in a variety of contexts, demonstrating enhancement in self-efficacy beliefs (Bautista, 2011; Morrell & Carroll, 2003; Narayan & Lamp, 2010). However, a handful of research studies have been directed towards investigating changes in self-efficacy beliefs in the context of content courses. Thus, above research questions examined the changes in science self-efficacy beliefs as well as the key factors that are responsible for
such changes. An analysis of such beliefs in the context of content courses is of particular importance to the science education community and make a significant contribution towards science teacher preparation, especially in the content-specific areas.

**Question 2**

What is the relationship between preservice elementary teachers’ science self-efficacy beliefs and science conceptual understanding?

**Question 2a**

What is the relationship between preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) and conceptual understanding of physics prior to participation in the specialized physics course?

**Question 2b**

What is the relationship between preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) and conceptual understandings of physics after their participation in the specialized physics content course?

**Question 2c**

What is the relationship between changes in science self-efficacy beliefs (PSTE and STOE) and changes in conceptual understandings of physics?

**Rationale**

The above set of research questions examined the interrelationship between preservice teachers’ self-efficacy and conceptual understanding of physical science. While several researchers propose that increase in science content knowledge contributes towards increase in science teacher efficacy (Cantrell et al., 2003; Leonard et al., 2011; Yilmaz-Tuzun, 2008), these contentions are not supported by evidence-based research.
Above research questions are targeted to provide empirical evidence to some of these claims. Research question 2a specifically investigated the relationship between preservice teachers’ preconceptions about science content and their prior beliefs about science teaching before the preservice teachers participate in the content course.

Researchers argue that specialized content courses present science content material in an investigative manner that could potentially shape preservice teachers’ preexisting beliefs resulting in enhanced confidence and appreciation towards science and science teaching (Duran et al., 2004; McLoughlin & Dana, 1999). Research question 2b investigated the relationship between self-efficacy beliefs possessed by preservice teachers and their science conceptual understanding after the completion of the instruction.

It is reasonable to expect that there might be changes in preservice teachers’ self-efficacy beliefs and conceptual understanding of the targeted science topics during the course; however, whether or not these two are related needs thorough investigation. Research question 2c specifically investigated the relationship between the changes in self-efficacy beliefs on both scales and changes in science conceptual understanding. Understanding the relationship between changes in science self-efficacy beliefs and science conceptual understanding provided important directions for preservice teacher education reform.

**Significance of the Study**

One of the greatest concerns in the science education community for the past few decades is to achieve scientific literacy for all students (AAAS, Benchmarks, 1991; 1993; Project, 2061). Of considerable concern is that significant numbers of elementary
teachers describing their preservice teacher preparation as ineffective, leaving them unprepared to teach science (Gess-Newsome, 1999; Nachtigall, 1990; Tilgner, 1990). Reform movements have raised questions about the way science instruction is taking place in preservice content training, particularly about the impact of traditional physical science content courses (McDermott, 1990). With regard to such reforms, the science teacher educators emphasize that preservice teachers’ beliefs about science serve as a lens through which they view themselves as future science teachers. However, there has always been a debate on whether or not mandating additional content coursework has the potential to enhance future elementary teachers’ science self-efficacy beliefs.

This study is significant in that the results provide a clear understanding of the relationship between preservice teachers’ science conceptual understanding and their science self-efficacy beliefs associated with participation in a specialized physics content course. The investigation of this relationship provide evidence of the extent to which science conceptual understanding contributed toward preservice teachers’ confidence to teach it. Rather than assuming any nature of links that may exist between science content knowledge and science self-efficacy beliefs, this study provides empirical evidence of such interrelationships through systematic investigation. The results of this study add important information to the field of preservice teacher education which currently lacks research-based evidence of the relationship between changes in science conceptual understanding and changes in science self-efficacy beliefs due to the inclusion of a specialized science content course for elementary education majors.
Summary of Chapters

This chapter provides the description of the problem, rationale for research questions and significance of the study in terms of its contribution to the field of science education. Chapter 2 provides the review of the relevant literature. Chapter 3 includes the research design and the details of the methodology that will be employed for this research. Chapter 4 reports the results of the research questions. Chapter 5 includes discussion of the study, limitations of the study, implications of the results, and suggestions for future research avenues in the area of preservice teacher preparation.
Figure 1. Theoretical Framework: Adapted from Shulman (1986) and Bandura (1997). The relationship between the conceptual understanding of physical science and science self-efficacy beliefs.
CHAPTER 2
LITERATURE REVIEW

Introduction
Over the past three decades, educational researchers have recognized that teachers’ self-efficacy strongly influences the instructional processes (Guskey & Passaro (1994). As a result, the investigation of elementary teachers’ self-efficacy beliefs has been of considerable focus of research in science teacher education. Earlier literature on self-efficacy grew out of Bandura’s conceptualization of self-efficacy construct as beliefs that influence one’s thought processes that guide subsequent actions in pursuit of the desired goal (Bandura, 1986; 1993). Following the identification of self-efficacy as a valuable psychological construct in teacher education, assessment of self-efficacy became a priority among researchers in the field. Research literature documents several attempts toward the construction of valid measures of teacher self-efficacy scales for both inservice and preservice teachers.

Ever since the development of instrument called Science Teaching Efficacy Belief instrument (STEBI) specific to elementary science teaching (Riggs & Enochs, 1990), a significant amount of studies have been conducted to explore preservice and inservice elementary teachers’ beliefs in a variety of contexts during teacher education programs. Moreover, the purpose of such extensive research conducted with regard to self-efficacy beliefs varied from investigating the effectiveness of innovative preservice methods and content courses (Brand & Wilkins, 2007) to exploring the factors that influence self-efficacy beliefs in a particular course setting (Narayan & Lamp, 2010).

Based on Bandura’s construct of self-efficacy, the purpose of this study was two-fold. The study was primarily concerned with how preservice teachers’ self-efficacy
beliefs change during the specialized science content course. Additionally, the study explored the relationship between science conceptual understanding and science self-efficacy beliefs. This review of existing literature was crucial for the purposes of the study in order to understand a holistic picture on past and present research regarding science self-efficacy beliefs in the field of teacher education.

**Literature Review Organization**

First section of this review begins with the meaning of self-efficacy beliefs as proposed by Bandura and some of the other definitions that reinforce Bandura’s definition of self-efficacy. The section also includes sources of self-efficacy and its relevance to preservice teacher population and literature on development of various instruments for assessing self-efficacy beliefs. Next, the second section presents research literature on studies relevant to elementary preservice science teacher education only. More specifically, the section systematically covers seminal research work on self-efficacy beliefs in the context of science methods courses, science content courses and overall preservice teacher preparation programs. Each of these sections present synthesis of the research literature under emerging themes that provide the overview of the factors that play key role in shaping self-efficacy beliefs. Research studies supporting each theme are addressed under each major theme. Under these sections, explicit attention was given to the research studies that suggest differing claims to the notion of how science content knowledge and self-efficacy beliefs are related. Finally, the chapter concludes with the summary of literature review including three themes and short discussion on how the present study contributes to the literature on science education and preservice teacher education.
Inclusion and Exclusion Criteria for Articles

Based on the focus of the study, three limiting factors were used as criteria for the inclusion or exclusion of articles. First, the studies focusing on exploring science self-efficacy beliefs of elementary preservice teachers were given preference over inservice elementary science teachers. However, seminal studies related to inservice elementary teachers or preservice secondary teachers are mentioned at times in support of assertions existing in the science self-efficacy research literature. Second, while there is abundant literature on self-efficacy, articles from peer-reviewed journals are included. The articles from practitioner journals are not included because they either demonstrated an instructional strategy or suggested inquiry lessons where self-efficacy was implicitly addressed as one of the outcomes. Only research-based articles that either used self-efficacy as a framework or lens to guide the study or as a construct investigated in the study were included. Third, although numerous research studies have been conducted in various disciplines that have adapted self-efficacy as a framework, studies specific to the science discipline and preservice teachers’ science self-efficacy beliefs are included.

Search of Research Articles

In the first round of search, articles were identified through a keyword search in databases including ERIC, Wilson Web (including Education Full Text), Wiley online library (including School Science & Mathematics), as well as through searches in science education journals such as the Journal of Science Teacher Education, Journal of Elementary Science Education, Journal of Research in Science Teaching, and Journal of Psychology. Another round of searches included keyword searches and phrases such as: self-efficacy and preservice elementary teachers, science methods courses and self-
efficacy, science content courses and impact of self-efficacy on preservice teachers in Web search engine called Google Scholar. The articles selected were published between the years 1990-2013, with few exceptions including articles published between the years 1977-1989 found in the microfiche section in university library. Because self-efficacy emerged as a powerful construct in science teacher education over the past 35 years, few articles before that era were only available in microfiche.

Teacher Self-Efficacy as a Construct

Self-efficacy as a construct was first conceptualized by Bandura (1977) as judgment of one’s capabilities that the actions performed will lead to a successful outcome. According to Bandura, the concept of self-efficacy beliefs consists of two distinct dimensions, outcome expectation and self-efficacy expectation. While outcome expectation is person’s belief that their behavior will produce desired outcomes, self-efficacy expectation is the person’s confidence to execute actions in a way to achieve desired goal (See Figure 2).

![Figure 2](image_url)

*Figure 2.* Representation of the difference between efficacy expectations and outcome expectations (Bandura, 1977).

Based primarily on Bandura’s identification of one’s behavior as dependent on outcome expectancy and sense of self-efficacy, Ashton and Webb (1982) developed a multidimensional model of self-efficacy. They extended Bandura’s theory to teachers and identified that the two dimensions, namely, teaching efficacy and personal efficacy
account for individual teacher differences in performing actions or making decisions regarding their own teaching. Gibson and Dembo (1984) applied both Bandura’s and Ashton & Webb’s theory to develop the questionnaire called Teacher Efficacy Scale and attempted to provide validation to the construct of teacher efficacy, which they defined as a “variable accounting for individual differences in teacher effectiveness” (p. 569). Their analysis of 208 elementary teachers’ responses on the questionnaire confirmed two-dimensionality of self-efficacy. Following this, Dembo and Gibson (1985) identified teachers’ sense of efficacy as a predictor of teacher’s classroom behavior that has significant impact on students’ achievement. Consistent with Bandura, Guskey & Passaro (1994) suggested that both dimensions of teacher self-efficacy are highly significant in elementary classrooms, especially science teaching, but act independently of each other. For instance, elementary teachers (especially beginning 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).

Several other studies attempted to build a comprehensive theoretical meaning of self-efficacy as well as to develop a valid instrument to measure it. Self-efficacy was further conceptualized as a dynamic construct that could potentially change with experiences gained, and has a “mobilization component” (Gist & Mitchell, 1992, p. 185) that helps individuals to adapt themselves to fit in complex situations (Bandura & Wood, 1989; Gist & Mitchell, 1992). Gist and Mitchell (1992) further defined self-efficacy as the “judgment about task capability that is not inherently evaluative” (p. 185). They extended the construct of self-efficacy into organizational behavior by proposing a model
of self-efficacy that provides understanding of “complexity and malleability” of self-efficacy construct (p. 183). Consistent with the Bandura’s theory of self-efficacy, Tschannen-Moran et al., (1998) defined teacher efficacy as teachers’ beliefs that shape their abilities to execute certain actions in desired situations, which can bring desired results. They proposed that teacher efficacy is context specific, situational and subject-matter specific. For instance, elementary teachers might be committed to teach other subjects effectively than science because they might perceive their science teaching as inadequate to help students attain higher levels of academic achievement.

**Four Sources of Self-Efficacy**

Bandura (1997) proposed four major sources of self-efficacy that play roles in determining self-efficacy expectations for an individual to perform a specific action (See Figure 3). The first factor, enactive mastery experiences, are supposed to impact self-efficacy beliefs to a larger extent as compared to other factors such as vicarious experiences, verbal persuasion and emotional arousal (Bandura, 1977, p. 198). Mastery experiences are a person’s own experiences of being successful in the past that not only add to person’s self-confidence to succeed in similar situations but also increase coping efforts in challenging situations. Vicarious experience, the second source of information on self-efficacy, is the belief in oneself to succeed after seeing evidence of others striving through similar situations and being successful. The third factor, verbal persuasion, refers to positive feedback received from others on their performance or “placebo effect” (Bandura, 1977, p. 198) that increases individual’s performance skills. Finally, the fourth source of self-efficacy, called emotional arousal, refers to one’s physiological and affective state that may influence anxiety and stress levels, which may further influence
an individual’s performance tasks. In a more recent study, Palmer (2006b) proposed three additional sources of self-efficacy along with Bandura’s sources: content cognitive mastery, cognitive pedagogical mastery and stimulated modeling. He also specified self-efficacy as an “accurate indicator of performance” where low efficacious persons tend to avoid the activity while high efficacious persons are enthusiastic and continue to make efforts to complete the task successfully.

Figure 3. Four modes of self-efficacy and outcome expectancy. Adapted from Dembo and Gibson (1985).

Several research studies have adapted Bandura’s sources of self-efficacy as a framework to understand the impact of various course interventions as well as the contribution of each source towards changes in preservice teachers’ science self-efficacy beliefs. The literature states some of the mastery experiences as either authentic experience gained within the courses (Gunning & Mensah, 2011) such as carrying on inquiry-based hands-on science investigations, classroom discussions, creating their own science lesson plans (Mulholland & Wallace, 2001), or successful classroom practices (Bandura, 1982; 1997; Bautista, 2011; Tschannen-Moran et al., 1998) in student teaching
and field experiences, and opportunities to reflect on their own teaching (Brand & Wilkins, 2007).

Vicarious experiences may include preservice teachers’ observing either other teachers’ successful performance in an actual classroom or watching videos of other teachers using effective science teaching models followed by reflection and discussion on different aspects of their teaching (Bautista, 2011; Gunning & Mensah, 2011). They may also include preservice teachers video-taping their own teaching practices followed by thorough reflection (Bautista, 2011) to understand critical elements for future teaching. Other than these experiences, preservice science teachers’ confidence is greatly enhanced by verbal persuasion, including positive feedback and encouragement received from science instructors, their own peers, school supervisors and family support (Bandura, 1997; Bautista, 2011). Finally, physiological and affective states of individual preservice teachers influence their ability to handle stress and anxiety while teaching science in the classroom (Bandura, 1997; Bautista, 2011; Gunning & Mensah, 2011). All these experiences collectively determine how well preservice teachers are prepared to teach science effectively in their future classrooms (See Figure 3).

**Instruments to Assess Teacher Self-Efficacy**

With the growing realization of self-efficacy as an important construct in teacher education (Gist & Mitchell, 1992), systematic efforts were made for developing valid and reliable instruments to measure self-efficacy beliefs (Bleicher, 2004). The earlier attempts to establish construct validity of self-efficacy includes development of the instrument by Gibson and Dembo (1984) to investigate the relationship between teacher self-efficacy and teacher classroom behaviors. The 30-item scale called Teacher Efficacy scale (TES)
provided evidence of multi-dimensional aspects of self-efficacy comprised of two distinguishable factors: general teaching efficacy (GTE) and personal teaching efficacy (PTE); however, construct validity was not well established.

Another instrument called the Science Teaching Efficacy Belief instrument (STEBI-A) was developed (Riggs & Enochs, 1990). The instrument is comprised of 25 items on a 5-point Likert scale ranging from ‘strongly agree’ to ‘strongly disagree’ measuring two factors, which researchers named as personal teaching efficacy and outcome expectancy. The modified version of STEBI-A was developed for the preservice teacher population called STEBI-B (Enochs and Riggs, 1990). This new version excluded two items from the original version (STEBI-A) and re-organized the questions in future tense to understand their perceptions about future teaching. Due to the popularity of STEBI-B as a valid and reliable instrument, it was widely used in conducting research to understand personal self-efficacy beliefs and outcome expectancy beliefs of preservice teachers. Bleicher (2004) made an attempt to re-examine the internal validity and reliability of STEBI-B. Although the revised version was statistically more reliable, researchers continue to utilize the original version of STEBI created by Enochs and Riggs (1990).

Other versions of STEBI-B were created in the context of other content areas; for example, the STEBI-CHEM (Rubeck & Enochs, 1991 in Bleicher, 2001) measured the beliefs in teaching chemistry. Similarly, the instrument called The Self-Efficacy Beliefs About Equitable Science Teaching (SEBEST) instrument was designed to measure the teachers’ self-efficacy beliefs in science teaching and learning in relation to socio-economic factors, gender, ethnicity and language minorities (Ritter, Boone & Rubba,
Another instrument was developed to measure preservice self-efficacy beliefs in teaching mathematics, called The Mathematics Teaching Efficacy Belief Instrument (MTEBI) (Enochs, Smith & Huinker, 2000). More recently, a five-point Likert scale instrument called Beliefs About Teaching (BAT) was designed for assessing preservice elementary science teachers’ beliefs about teaching methods, classroom management, assessment techniques and science content (Yilmaz-Tuzun, 2008). Furthermore, researchers working in specific cultural contexts such as Turkey and Pakistan created valid instruments to measure preservice teacher populations in those areas.

**Research studies on measuring preservice teachers’ science self-efficacy**

A number of studies have been conducted to examine the impact of specific courses (e.g., methods and content) and of student teaching on self-efficacy. At this point, it is important to note that research studies have used both self-efficacy and confidence interchangeably. Therefore, while highlighting specific studies in this section, the usage of either term is kept the same as suggested by the authors of the study.

In general, studies suggest that the teacher education programs may create positive impacts on preservice teachers’ self-efficacy beliefs, but this is not always the case. Tables 1.1 through 1.6 show the distribution of studies based on the study context, methods employed and reported findings. Each table is followed by its own section that compares and contrasts research studies in similar contexts. Some studies are considered in multiple categories as they investigated preservice teachers’ self-efficacy beliefs in multiple contexts. Also, there are some studies that are not mentioned in the table but only briefly discussed.
Impact of Science Methods Courses on Science Self-efficacy

Preservice teachers entering science methods coursework have a broad range of science self-efficacy beliefs (Cantrell et al., 2003); however, engagement in well-designed methods courses could bring positive changes in these beliefs (Palmer 2006a). The literature suggests various models for science methods courses that are offered in various universities. In some universities, science methods courses include teaching instructional strategies along with understanding elementary science content through various hands-on activities (Cantrell, 2003). In many universities, methods courses are taught in conjunction with teaching practicums wherein preservice teachers practice teaching science lessons in actual elementary classrooms. A number of studies have focused on investigating how methods course impact preservice teachers’ self-efficacy beliefs. These studies mainly utilized pre-post-test design for demonstrating the changes in preservice teachers’ science self-efficacy beliefs.

In the study conducted by Cantrell (2003) changes in preservice teachers’ self-efficacy beliefs were compared for two different groups. While the treatment group comprised of preservice teachers (N=24) enrolled in elementary science methods course, another group of 13 students were enrolled in combined science methods and a practicum course. There were no significant differences between the STEBI-B pre-test scores of both groups. While students in the combined methods and practicum course showed gains in science self-efficacy beliefs on both scales, the methods group showed gains in PSTE scores only. This finding is consistent with other studies in the literature that demonstrated no significant gains in STOE scores over the methods course model (Morrell & Carroll, 2003).
Based on the results from Cantrell’s (2003) study, one can argue that the additional component of practice teaching within the methods courses may benefit towards increase in preservice teachers’ science self-efficacy beliefs on both scales. Cantrell’s study did not explicitly highlight the science practicum as the most influential factor that boosted students’ confidence, but the science practicum was a significant factor in Palmer’s study (2006a). In Palmer’s study, the science practicum appeared as most effective in not only enhancing preservice teachers’ science efficacy beliefs but also in retaining their beliefs a year after the methods course concluded. Unlike in Cantrell’s study, the students in Palmer’s (2006a) study were administered the STEBI-B three times as pre- and post-test as well as delayed post-test administered after the completion of science methods course. Besides this, in Palmers’ (2006a) study, a science teaching practicum was not part of the science methods course and was offered immediately after the end of the course.

Both studies suggest that the practicum experiences are essential in building confidence for teaching science before they enter into the teaching profession. The study conducted by Settlage (2000) also supports the fact that providing opportunities to try out instructional strategies learned within the methods course itself may be beneficial to students and influence their self-efficacy beliefs. The study is significant because it focuses on identifying the relationship between changes in preservice teachers’ self-efficacy beliefs and their understanding of the learning cycle as an effective instructional strategy. The findings of the study are consistent with Cantrell (2003) where watching video footage of exemplary teachers using learning cycle instructional tool and opportunities to teach mini-lessons to their peers enhanced students’ science self-efficacy
beliefs. However, it is worth noting that students’ performance on the learning cycle test was positively correlated with the STOE, but did not correlate with PSTE scores. The results suggest that although preservice teachers’ were convinced that teaching based on the learning cycle does produce successful learning outcomes, but their increased understanding of the learning cycle does not account for changes in their personal beliefs about science teaching.

Some studies such as Cantrell (2003) and Gunning and Mensah (2011) argue that a science practicum should be an integral part of a science methods course even though time devoted to teaching would be short. This is important in order to lay a strong foundation for a more rigorous science teaching in the future (Gunning & Mensah, 2011). However, other studies such as Palmer’s (2006a) suggest that a teaching practicum should be immediately followed by the science methods course because students in their study maintained high level of self-efficacy gained during the science methods course during their field-placements. Authors argue that once the students attain confidence in how to teach science in their methods courses, they are expected to embrace science teaching opportunities to a large extent and maintain their high science teaching self-efficacy in future (Palmer, 2006a).
### Table 1.1

Empirical studies on investigating preservice teachers’ science self-efficacy beliefs in science methods course

<table>
<thead>
<tr>
<th>Purpose of the research study</th>
<th>Authors</th>
<th>Research Methods</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of science methods course on preservice teachers’ science self-efficacy</td>
<td>Cantrell (2003)</td>
<td>- Quantitative (Pre-post design implementing STEBI-B in combined methods and practicum and methods only group)</td>
<td>Significant gains in both scales (PSTE &amp; STOE) for methods and practicum group whereas no significant gains in STOE scores for methods only group.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Qualitative (Interviews)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Palmer (2006a)</td>
<td>- Quantitative (Pre-post and delayed post-test design implementing STEBI-B)</td>
<td>Significant gains in both scales (PSTE &amp; STOE) even after delayed period of 9 months. Science practicum was a significant factor.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Qualitative (Interviews)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Settlage (2000)</td>
<td>Quantitative (Pre-post design, implementation of STEBI-B, Learning Cycle test, and Attitude Inventory), Correlational Analysis</td>
<td>Learning cycle test positively correlated with the STOE, but did not correlate with PSTE scores. Negative correlation between attitude and self-efficacy scales.</td>
</tr>
</tbody>
</table>

### Impact of Science Methods Course Experiences on Self-Efficacy

A number of researchers suggest that prior experiences influence teachers’ decisions about their classroom instruction (Nespor, 1987; Pajares, 1992). Bandura (1997) linked past experiences gained by teachers during early stages of teacher preparation to teachers’ self-efficacy beliefs. Because experiences shape teachers’ beliefs towards science teaching and overall instructional practices, a number of studies were
conducted to investigate preservice teachers’ experiences within teacher preparation courses.

In general, it has been found that science teaching self-efficacy is highly influenced by the experiences preservice teachers gain within science methods courses. Science methods courses provide a wide range of inquiry based hands-on experiences and model teaching strategies that preservice teachers could utilize in their future elementary classroom (Rice & Roychoudhury, 2003). Research studies report that exposing preservice teachers to variety of rich experiences within the science methods courses are successful in enhancing preservice teachers’ confidence to a larger extent. For instance, Rice and Roychoudhury (2003) found that the students’ confidence in the methods course was enhanced by the modeling of appropriate instructional strategies such as learning cycle lessons, hands-on activities and group discussions.

While findings of the study conducted by Rice and Roychoudhury (2003) were based on qualitative methods only, similar findings were obtained from studies employing both qualitative as well as quantitative methodology. For instance, the studies conducted by Palmer (2006b) and Bautista (2011) employed quantitative methodology including administration of STEBI-B (Enochs & Riggs, 1990) to preservice teachers as pre-and post-test along with open-ended questions and informal surveys. All aforementioned studies utilized instructional practices in methods courses that have been reported effective in literature, such as using the learning cycle is well aligned with National Science Education Standards (NRC, 1996). Moreover, studies have shown that preservice teachers’ understanding of the learning cycle contributed towards increase in their beliefs about their ability to impact student learning in future (Settlage, 2000).
Both Rice and Roychoudhury’s (2003) and Palmer’s (2006b) studies have important implications towards the design of science methods courses. While both studies recommended instructional environments fostering hands-on activities along with rich group discussions, they 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) study raised an issue about the preservice teachers’ lack of appropriate science background knowledge, which was one of the major hindrances towards their confidence in science teaching.

Yoon, Pedretti, Bencze, Hewitt, Perris, and Oostveen (2006) reported similar concerns from the preservice teachers’ responses to a questionnaire administered at the beginning of a methods course. In most of the student responses, lack of prior science content knowledge was the main factor for low self-efficacy beliefs (Yoon, et al., 2006). Similarly, in Palmer’s (2006b), and only a small percentage of students (9%) indicated an increase in confidence due to improved understanding in science concepts at the end of the course. Both studies suggest that hands-on experience enhanced self-efficacy and content knowledge to some extent; however, an interesting question is whether or not such increased content understandings had an effect on preservice teachers’ self-efficacy or vice-versa. These studies present the need for research on the relationship between science content understanding and self-efficacy in science content as well as methods courses.

A number of studies have explored the factors that affect preservice teachers’ self-efficacy in methods courses taking Bandura’s notion of self-efficacy as the framework to guide their study. Bandura proposed mastery experiences to be most powerful in
enhancing self-efficacy beliefs because they offer firsthand experiences where the person is actively engaged in the learning process (for example, teaching a science lesson). On similar lines, few studies provide evidence that mastery experiences has greater potential to influence preservice teachers’ science self-efficacy as compared to the other sources such as vicarious, social persuasion and physiological states (Bandura, 1997; Brand & Wilkins, 2007), others argue that additional sources of self-efficacy such as vicarious experiences could be as powerful in enhancing science self-efficacy beliefs (Bautista, 2011; Gunning & Mensah, 2011, Yoon et al., 2006). In the study conducted by Brand & Wilkins (2007), mastery experiences such as learning science content in constructivist environment as well as planning and implementing inquiry-based lessons employing modeled teaching strategies seemed to enhance preservice teachers’ self-efficacy within combined science and mathematics methods course. This finding is consistent with the study conducted by Bautista (2011) where a majority of students mentioned that opportunities to teach a science lesson greatly impacted their science self-efficacy beliefs. Unlike previous studies, Gunning and Mensah (2011) focused on in-depth analysis of a single case, where a preservice teacher’s self-efficacy was examined in the context of the class as a whole. The study suggests that mastery experiences such as microteaching units and in-class discussions were the two factors that influenced the most in shaping her perception of her being a science teacher.

All of the above studies provide evidence of improved self-efficacy beliefs through mastery experiences, common outcomes in many of the preservice teachers’ responses. Among these responses, teaching practices embedded within science methods courses seems to have greatest impact on self-efficacy beliefs. Both Brand & Wilkins
Gunning & Mensah (2011) argue that even though the opportunity to teach in actual classroom as part of science methods course is limited by time and resources, is instrumental in enhancing their confidence to teach science. Research studies in past have also alluded to teaching practices as first hand opportunity for preservice teachers to apply inquiry-based strategies along with content learned in content or methods courses (Bandura, 1982; Ginns, Tulip, Watters & Lucas, 1995; Tschannen-Moran, Hoy & Hoy, 1998).

Despite the fact that mastery experiences was found to be most influential, studies also report that providing variety of experiences such as vicarious experiences could significantly contribute towards increase in self-efficacy (Bautista, 2011; Yoon et al., 2006). Specifically, watching video cases of expert teaching seemed to be widely used and stood out as a strong source of self-efficacy. For instance, reports from the students’ posts in online discussion board activity suggest that watching exemplary video-cases of effective science lessons allowed students to establish meaningful connections between theoretical knowledge and practical application of it (Yoon et al., 2006). Students reported that this experience created positive impacts on their self-efficacy beliefs and improved pedagogical content knowledge; however, there was no evidence of increases in science content knowledge for these students. This finding is in consistent with findings from the study conducted by Settlage (2000) where viewing video on learning cycle instructional tool had positive effect on preservice teachers’ outcome expectancy beliefs.

Among the studies focusing on factors that affect self-efficacy beliefs in science methods courses, the study conducted by Palmer (2006b) is worth mentioning. The study
is unique because of the fact that even though the methods course that did not provide any mastery experiences to preservice teachers, there was significant increase in their science self-efficacy beliefs. Palmer’s study made significant contribution by providing three additional sources of self-efficacy other than those suggested by Bandura. These sources are cognitive content mastery (experiences that lead to understanding of science concepts), cognitive pedagogical mastery (experiences that lead to understanding of science teaching instructional techniques) and stimulated modeling (role playing the elementary classroom).

The study employed both qualitative and quantitative methods to investigate the contribution of various sources of self-efficacy. STEBI-B was administered as pre- and post-test as well as informal surveys were administered at three time points: week 5, week 8, and at the end of the course. Results from the analysis of 108 STEBI-B responses suggested significant increases in self-efficacy on both scales (PSTE and STOE). Coding of informal survey responses was based on Bandura’s (1997) sources of self-efficacy; however, a few new categories emerged from the analysis of the data, including cognitive content mastery, cognitive pedagogical mastery, and stimulated modeling.

Many students suggested that learning about the teaching techniques that they feel confident to use in future boosted their confidence, thus cognitive pedagogical mastery came out as the important contributor towards science self-efficacy. Similarly, Brand & Wilkins (2007) found traces of social persuasion such as encouragement by instructor and peers, and stress reduction as sources of self-efficacy in few preservice teachers’ interview responses.
To conclude, providing ample opportunities such as inquiry-based experiences, meaningful discussions and practice teaching during science methods coursework greatly impact preservice teachers’ self-efficacy beliefs. Furthermore, the courses offered in preservice programs should provide opportunities for all sources of self-efficacy suggested by Bandura (1997) four modes for developing strong foundation for future endeavors (Gunning & Mensah, 2011). Additionally, preservice teachers entering teacher preparation programs may vary in terms of science experiences and their teaching beliefs, an approach that allows them to progress and process their skills would increase their commitment to teach science effectively.

Although studies suggest that science methods courses effectively enhance self-efficacy beliefs; the question is whether or not the amount of exposure to science content in these courses is adequate. None of the above findings from research studies suggest increased content knowledge in methods courses either by watching science lessons (Yoon et al., 2006) or through mastery experiences. Thus, an overarching question arises regarding the amount of content being addressed in science methods courses, considering the fact that preservice teachers reported limited science content knowledge as one of the barriers towards changes in science self-efficacy (Palmer, 2006b; Rice & Roychoudhury, 2003; Yoon et al., 2006). Clearly, it can be argued that negative dispositions prior to entering methods courses may influence preservice teachers’ science self-efficacy beliefs. Thus, it seemed logical to explore the relationship between understanding of science and self-efficacy beliefs, taking into account the present status of elementary science instruction.
### Table 1.2

*Empirical studies on investigating factors effecting preservice teachers’ science self-efficacy beliefs in science methods course*

<table>
<thead>
<tr>
<th>Purpose of the research study</th>
<th>Authors</th>
<th>Research Methods</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigating factors effecting self-efficacy in science methods courses</td>
<td>Rice &amp; Roychoudhury (2003)</td>
<td>-Qualitative (written self-evaluations, open-ended items, course evaluations, interviews)</td>
<td>Students’ confidence was enhanced. Common sources were modeling of learning cycle lessons, hands-on activities and group discussions</td>
</tr>
<tr>
<td>Palmer (2006b)</td>
<td>- Quantitative (Pre-post design implementing STEBI-B) - Qualitative (Open-ended questions, informal surveys for identifying contribution of each source towards science self-efficacy)</td>
<td>Science self-efficacy increased at the end of the course. Cognitive pedagogical mastery (how to teach) and cognitive self-modeling (visualizing own teaching) were common sources</td>
<td></td>
</tr>
<tr>
<td>Bautista (2011)</td>
<td>- Quantitative (Pre-post design implementing STEBI-B) - Qualitative (Open-ended questions)</td>
<td>Significant gains in both scales (PSTE &amp; STOE) at the end. Enactive mastery and cognitive pedagogical mastery were major sources.</td>
<td></td>
</tr>
<tr>
<td>Brand and Wilkins (2007)</td>
<td>- Qualitative (Open-ended questions, written reflections) - Descriptive statistics (information on frequency of sources)</td>
<td>All sources (mastery experiences, vicarious experiences, social persuasion and self-reduction) influenced self-efficacy beliefs. Mastery experiences were most influential.</td>
<td></td>
</tr>
<tr>
<td>Gunning and Mensah (2011)</td>
<td>Qualitative – Single case study (Initial &amp; final open-ended survey, observations, interviews, artifacts)</td>
<td>Mastery experiences were most influential. Microteaching unit and in-class discussions contributed the most.</td>
<td></td>
</tr>
<tr>
<td>Yoon, et al., (2006)</td>
<td>Qualitative (open-ended questionnaire, small group reflections, online discussion board comments, observations, interviews)</td>
<td>Watching video cases demonstrating successful teaching increased science self-efficacy beliefs. Pedagogical content knowledge improved but no evidence of increase in science content knowledge.</td>
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</tr>
</tbody>
</table>

**Impact of Science Experiences on Preservice Teachers’ Self-Efficacy**

Many researchers have suggested that preservice teachers’ science experiences may impact their science teaching self-efficacy beliefs for future science teaching. These experiences can be either prior high school science experiences before entering the teacher preparation program or the experiences gained through college science coursework. Studies that focused on investigating the impact of prior science experiences or the number of courses taken in college provide mixed results.

In the study conducted by Jarrett (1999), 37% of the preservice teachers mentioned their elementary and high school experiences as positive. Furthermore, college science experiences such as inquiry-based hands on activities along with modeled inquiry instructional technique were able to enhance preservice teachers’ confidence and interest in science teaching. The findings from Hechter’s study (2011) are consistent with Jarrett (1999) where the college science content training makes significant difference in preservice teachers’ personal beliefs in their ability to teach science, which was demonstrated by increase in PSTE scores. Another similarity between the two studies is that the number of science content courses taken by preservice teachers and perceptions about the prior school science experiences were found to contribute towards science self-efficacy changes.
While in Jarrett’s study, preservice teachers’ elementary and high school experiences as well as number of college science courses taken were the greatest contributors towards building confidence, the preservice teachers in Rice & Roychoudhury’s (2003) study and Yoon et al., study (2006) expressed serious concerns over their past science learning experiences.

The study conducted by Tosun (2000) yielded contrary results from those reported from study conducted by Jarrett (1999). It was found that at the end of the course, both high and low achievement groups (based on prior experiences) showed significant changes in self-efficacy on PSTE scale. The fact that both groups were statistically similar on PSTE scale at the beginning and end of semester suggest that prior science experiences and achievement were not the contributing factors for changes in personal self-efficacy beliefs during the course.

Bleicher and Lindgren (2005) took one step further to understand the relationship between preservice teachers’ science conceptual understanding and self-efficacy beliefs. Unlike traditional methods courses, this particular course offered a constructivist environment for learners to gain science understanding along with relevant pedagogical skills. While self-efficacy increased on both scales, the relationship between pre-post science conceptual understanding and pre or post personal self-efficacy beliefs was significant only for PSTE scores. Consistent with Jarrett’s and Hechter’s study, students who reported prior science experiences as positive had significantly higher gains in pre- and post-PSTE scores.

It is worth noting that none of the studies showed gain in preservice teachers’ STOE scores due to the effects of adding a course. While this finding is consistent with
other studies in the literature showing that STOE changes are difficult (Cantrell, 2003; Cantrell et al., 2003; Morrell & Carroll, 2003), it can be concluded from Tosun’s study (2000) and Hechter’s study (2011) that neither science content courses taken before entering college nor college science course work taken impact preservice teachers’ belief that their future students could learn effectively from them.

Table 1.3

_Empirical studies on investigating impact of prior science experiences in shaping preservice teachers’ science self-efficacy beliefs_

<table>
<thead>
<tr>
<th>Purpose of the research study</th>
<th>Authors</th>
<th>Research Methods</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of science experiences (either prior experiences or experiences within science methods courses)</td>
<td>Jarrett (1999)</td>
<td>Quantitative (Science interest and confidence rating scale)</td>
<td>Significant relationship between overall interest in science and confidence. Main contributing factors were elementary and high school science experiences, and number of college science courses taken.</td>
</tr>
<tr>
<td>Tosun (2000)</td>
<td>Qualitative (Science achievement/experience history questionnaire, interviews)</td>
<td>High achievement in science did not change participants negative feelings towards science, as a result had serious impact on science self-efficacy beliefs</td>
<td></td>
</tr>
<tr>
<td>Hechter (2011)</td>
<td>Quantitative (Pre-post-test, and retrospective pre-test design implementing STEBI-B)</td>
<td>Prior school science experiences and number of college science courses significantly impact PSTE but not STOE beliefs.</td>
<td></td>
</tr>
<tr>
<td>Bleicher &amp; Lindgren (2005)</td>
<td>Mixed-method design (Pre-post administration of science conceptual understanding test, STEBI-B, reflective journals, focus-group discussions, confidence rating)</td>
<td>Significant gains in science test and both PSTE and STOE scores. Significant correlations between pre-post science test and pre-post PSTE, but no relationship pre-post science test and pre-post STOE scores.</td>
<td></td>
</tr>
</tbody>
</table>
Impact of Science Content Courses on Self-efficacy

The literature suggests that specialized content courses utilize appropriate research-based methodologies and inquiry-practices that probe students’ understanding of science. While studies on specialized content courses mainly focused on evaluating the course-design in particular, few studies tried to explore the impact of science courses on preservice teachers’ perceptions or confidence to teach science.

In general, research studies posit that preservice teachers tend to embrace learning science content through appropriate models of teaching, their views and perceptions regarding newly-designed content courses certainly vary. For instance, in the study conducted McLoughlin and Dana (1999), the experimental course situated around constructivist theory of learning content consistent with the K-8 state content standards was successful in increasing preservice teachers’ passion in science. Although several aspects of the course such as pedagogically-oriented assignments and activity-based learning experiences seemed to work well with students, some students expressed concern over the pace with which the content was delivered to them. Nevertheless, the course experiences enhanced prospective teachers’ confidence and their appreciation towards science at the end, even though their journeys were full of frustrations due to initial struggle in understanding content rooted in pedagogy.

Similar results were found from the study conducted by Doster et al., (1997) where prospective middle school teachers initially expressed anxiety over the science content as well as the new classroom setting which was different from their past experiences of learning via lecture. The study results also suggested that exposure to inquiry-learning and modeling strategy for an extended period of time helped students
appreciate the inquiry method as they felt better prepared to teach science concepts. Consistent with concerns over the amount of content being taught with a new approach, the preservice teachers in the study conducted by Duran et al., (2004) were uncomfortable in the innovative physics content course initially, but soon their frustrations disappeared once they realized the potential in teaching through inquiry approach.

Although none of the above studies explicitly focused on exploring changes in self-efficacy in preservice teachers within a specific course context, they make significant contribution about the format and structure of the science content course as received by preservice teachers. Despite of some negative expressions shown by participants due to their unpreparedness for the constructivist environment they were not typically aware of, all studies evidenced increase in preservice teachers’ confidence and interest towards science teaching and learning.

A handful of studies focused on determining the changes in self-efficacy in light of investigating the effectiveness of science content courses. The study conducted by Narayan & Lamp (2010) explicitly focused on exploring factors influencing preservice teachers’ self-efficacy in a physical science content course built around constructivist and inquiry-based teaching approach. At the beginning of the course most of the participants reported negative prior science experiences. At the end of the course participants reported an increase in their self-efficacy beliefs through participation in various mastery experiences (Bandura, 1997); inquiry-based activities and modeling of appropriate practices by the course instructor were the predominant contributors toward such an increase. These results are consistent with the findings from the study conducted by
Crowther & Bonnstetter (1997) and Reisetter, Bruning and Veomett (1998). They found that in spite of preservice teachers’ initial concerns regarding the new ‘Hands-On Biology’, the course increased their confidence in science as well as brought positive changes in their self-efficacy (Reisetter, Bruning and Veomett, 1998; Friedrichsen, 2001). Because their results are brief, that there is no opportunity for generalizations of such findings.

Table 1.4

Empirical studies on investigating impact of science content courses on preservice teachers’ science self-efficacy beliefs

<table>
<thead>
<tr>
<th>Purpose of the research study</th>
<th>Authors</th>
<th>Research Methods</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of science content courses</td>
<td>McLoughlin &amp; Dana, (1999)</td>
<td>Qualitative (open-ended questions, field-notes, interviews, artifacts)</td>
<td>Mixed feelings were held by participants of the course. Pedagogically-oriented assignments and activity-based learning enhanced confidence.</td>
</tr>
<tr>
<td>Doster, et al. (1997)</td>
<td>Qualitative (Field-notes, focus group interviews)</td>
<td>Exposure to Inquiry-learning and modeling strategy for an extended period of time helped students as they felt better prepared to teach science concepts.</td>
<td></td>
</tr>
<tr>
<td>Duran, et al. (2004)</td>
<td>Qualitative (Focus-group interview)</td>
<td>After initial concern with new constructivist environment, students felt inquiry-method to be beneficial, thus increased their confidence in science teaching.</td>
<td></td>
</tr>
<tr>
<td>Narayan &amp; Lamp (2010)</td>
<td>Qualitative (individual and focus group interviews, pre- and post-concept tests, participant lesson plans)</td>
<td>Self-efficacy increased due to mastery experiences such as active participation in inquiry-based activities and modeling of instructional strategies.</td>
<td></td>
</tr>
</tbody>
</table>
Impact of Science Teacher Preparation Programs on Self-efficacy

While most of the research regarding preservice science self-efficacy beliefs demonstrates changes over a single semester course, few attempted to investigate the overall change in self-efficacy during teacher preparation programs. Morrell & Carroll (2003) investigated the impact of science content courses, science methods courses and student teaching on preservice teachers’ science self-efficacy beliefs. Statistical analysis of the data revealed that there was no significant difference in PSTE or in STOE scores for students enrolled in science content courses and a student teaching seminar, but significant gains in the PSTE were found for the students in science methods courses (Morrell & Carroll, 2003). Several studies support this finding that the number of science content courses taken (Hechter, 2011; Tosun, 2000) and the student teaching experiences did not contribute towards improving science self-efficacy beliefs (Plourde, 2002, Settlage, Southerland, Smith & Ceglie, 2009).

It is worth noting that in Morrell and Carroll’s (2003) study preservice teachers’ STOE scores did not change during their involvement in methods course, consistent with results from the study conducted by Cantrell (2003). On the contrary, some studies have shown that interventions with science methods course enhance preservice teachers’ science self-efficacy on both scales (Palmer, 2006a). Nevertheless, there is a consensus in the literature that changes in outcome expectancy beliefs are at times difficult to achieve through science methods courses only, without sufficient practice teaching science in actual classrooms (Morrell & Carroll, 2003; Riggs & Enochs, 1990).

Cantrell et al., (2003) conducted a similar study to examine preservice teachers’ science self-efficacy at every stage of the teacher preparation program, including the
introductory methods course, advanced methods course and student teaching opportunities (Cantrell et al., 2003). While significant increases in PSTE scores were found over the three semester coursework, the number of science courses significantly contributed towards an increase in the STOE for the students in student teaching group. This finding is in contrast with several studies in the literature that show that number of courses does not affect self-efficacy beliefs (Morrell & Carroll, 2003; Tosun, 2000).

Along with overall changes in self-efficacy, the Cantrell et al., (2003) study also explored the relationship between preservice teachers’ self-efficacy and other factors such as gender, prior science experiences, and time spent in teaching science in actual classrooms. During science coursework, male PSTE scores were higher compared to females, but no difference was found for the methods group or student teacher group of students. The findings from Azar (2010) refute these findings, showing no correlation between self-efficacy and gender. Consistent with other studies in literature, time spent by preservice teachers teaching science in actual classrooms seemed to greatly enhance science self-efficacy beliefs (Gunning & Mensah, 2011; Mulholland & Wallace, 2001).
Table 1.5

*Empirical studies on investigating impact of science preparation program on preservice teachers’ science self-efficacy beliefs*

<table>
<thead>
<tr>
<th>Purpose of the research study</th>
<th>Authors</th>
<th>Research Methods</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of science preparation programs/courses (science content, methods and student teaching)</td>
<td>Morrell &amp; Carroll (2003)</td>
<td>Qualitative pre-post design implementing STEBI-B in various courses</td>
<td>Significant gains in PSTE scores for methods group, no significant gains in either scale for students in science content courses or student teaching semester.</td>
</tr>
<tr>
<td></td>
<td>Cantrell, et al. (2003)</td>
<td>Quantitative (Pre-post design implementing STEBI-B in various courses, demographic survey)</td>
<td>Significant gains in PSTE scores for all courses, but STOE gains were significant in student teaching group only. Classroom teaching experiences contributed the most towards increase in self-efficacy.</td>
</tr>
</tbody>
</table>

**Concluding Remarks**

The literature review can be summarized with three major themes. First, prior experiences encountered early in life may influence science self-efficacy belief; however, a high quality preservice science experience has potential to overcome the prior negative experiences and increasing self-efficacy beliefs. Second, although science content knowledge seems to be one of the major factors that play a crucial role in future science teaching, its relationship with science self-efficacy beliefs needs logical attention in science education research. Third, while the list of factors effecting preservice teachers’ science self-efficacy beliefs as described in the literature is exciting; nevertheless, to bring long-lasting results, research should be continue to explore the effects of various kinds of curricular support provided during such a delicate stage of teacher preparation.
As identified in the above themes, the present study (1) attempted to fill in the gap in the literature by providing a comprehensive picture of the relationship between content knowledge and self-efficacy beliefs and (2) explored preservice teachers’ self-efficacy beliefs and added to the existing literature on factors influencing preservice science self-efficacy beliefs in the context of content course. Thus, the findings of this study makes a significant contribution to the literature on both science education and preservice teacher education.
CHAPTER 3
METHODOLOGY

Introduction

The purpose of this study was to examine the changes in science self-efficacy beliefs of preservice elementary science teachers before and after their participation in a specialized physics content course. Additionally, the study explored the relationship between the changes in science self-efficacy beliefs and changes in physical science conceptual understanding. According to research literature, another factor beyond science self-efficacy beliefs that may affect future elementary science instruction is the science content knowledge (Cantrell, et al., 2003; Rice & Roychoudhury, 2003; Tosun, 2000; Wenner, 1993). While there is consensus among researchers that both science self-efficacy and science conceptual knowledge are critical for elementary science instruction, the few studies conducted that explore the link between the two constructs have provided mixed results. These conflicting results clearly suggest the need for ongoing investigation of the interrelationship that may exist between science conceptual understanding and science self-efficacy beliefs held by preservice teachers. This study was designed to provide a logical relationship between science conceptual understanding and science self-efficacy beliefs.

Organization of the Chapter

This chapter reviews the research questions that guide the study and presents research methods. Discussion on the research design includes the methodological approach and its rationale for the study followed by the research context. Discussion on the research context includes detailed description on the setting, the target population and
samples, followed by data collection and analysis techniques. The stages of data
collection including implementation of instruments and measures to ensure reliability and
validity within a specific time frame are discussed in detail. Following this, the various
phases of data analysis are outlined. The data analysis procedures including both
qualitative and quantitative analysis are discussed in detail.

**Research Questions**

**Question 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?

**Question 1a**

Is there a significant change in science self-efficacy (PSTE and STOE) beliefs of
preservice elementary teachers participating in the specialized physics content course?

**Question 1b**

What factors associated with the specialized physics content course contribute to
changes in preservice elementary teachers’ science self-efficacy (PSTE and STOE)
beliefs?

**Significance of the Question Order**

The research questions listed above are designed in a sequential order to guide
data collection and analysis procedures in the same order. The first research question is
informed by the findings of the two sub-questions 1a and 1b. The questions were shaped
such that the data collection, analysis and findings from one phase, as explained in detail
in sections to follow, consequently informed other research phases. For instance, the
participants for research question 1b were selected after the initial analysis and results
from research question 1a. While research question 1a relied on quantitative methods of data collection and analysis, research question 1b relied on qualitative methods. It was believed that the findings from both methods provide a more complete understanding of changes in participants’ self-efficacy beliefs and the factors associated with these changes.

**Question 2**

What is the relationship between preservice elementary teachers’ science self-efficacy beliefs and science conceptual understanding?

**Question 2a**

What is the relationship between preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) and conceptual understanding of physics prior to participation in the specialized physics?

**Question 2b**

What is the relationship between preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) and conceptual understandings of physics after their participation in the specialized physics content course?

**Question 2c**

What is the relationship between changes in science self-efficacy beliefs (PSTE and STOE) and changes in conceptual understandings of physics?

**Research Design**

To answer the research questions posed, the study utilized the mixed methods embedded design approach including three phases of data collection and analysis. These phases occurred over a period of 16 weeks during two semesters, Spring and Fall 2013.
According to Morse and Niehaus (2009), the mixed methods design enhances the understanding of the complex phenomena explored as well as provide a better comprehensive picture of the phenomena than a single method design. Both science self-efficacy and its relationship with science conceptual understanding are complex phenomena, thus mixed methods design was well suited for this study.

**The Pragmatic Approach**

Creswell and Plano Clark (2007) describe pragmatism as the paradigm or the philosophical stance typically taken by researchers using mixed methods design in their research. Historically, quantitative approach was taken by positivists, which was contradicted by qualitative researchers taking naturalistic or constructivist approach to guide their research (Hatch, 2002). The pragmatic approach allows researcher to mix both methods, yet have tenets from both qualitative and quantitative methods.

Pragmatic approach utilizes common philosophical elements from two distinct worldviews: post-positivism or deductive approach and constructivism or inductive approach (Plano Clark & Creswell, 2008). The ontological, epistemological, axiological, and methodological assumptions of the pragmatic approach are drawn from both deductive and inductive approaches. These assumptions further inform research questions being investigated in this study, methods used, and reporting of the data. Table 2 explains the assumptions of pragmatic approach as summarized by Creswell and Plano Clark (2007) as well as Plano Clark and Creswell (2008).
Table 2

Assumptions of the pragmatic approach

<table>
<thead>
<tr>
<th>Ontology (Nature of reality)</th>
<th>Epistemology (Relationship between what is known and who holds knowledge)</th>
<th>Axiology (Role values play in research)</th>
<th>Methodology (The process of research)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singular and multiple realities exist. Individuals have their own unique interpretations of the single “real world”</td>
<td>Primary importance is on the research question and researchers focus on “what works” and practice.</td>
<td>Multiple stances (included both biased and unbiased perspectives)</td>
<td>Mix of methods: Researchers collect both quantitative and qualitative data and combine them in a “regulated fashion that produces the most effectiveness” (Maxcy, 2003)</td>
</tr>
</tbody>
</table>

Embedded Mixed Methods Design

This research study utilizes an embedded mixed methods design (Tashakkori & Teddie, 2010). According to Creswell and Plano Clark (2007), researchers using embedded design could embed either a qualitative component within a quantitative study or vice versa, either one serve as the primary source and another as a secondary source of data. The design is particularly suitable for this study as qualitative data is embedded within a large quantitative study. While quantitative results document the potential changes in science self-efficacy beliefs, qualitative results enhance the understanding of the processes related to how and why these changes occurred within the research context.

While there are a number of variants in mixed methods designs, the criteria for choosing the mixed-methods design is determined by four factors: implementation of data collection, priority of the quantitative vs. the qualitative approach, the stage of
integration where quantitative and qualitative methods are combined in the research process, and the theoretical perspective taken by researcher in the study (Creswell, Plano Clark, Gutmann and Hanson, 2003). Table 3 illustrates the criteria for decision-making in determining the embedded design. The details of quantitative and qualitative data collection and analysis methods aligned with the research questions are explained in the section discussing data collection and analysis strategies.

Table 3

Criteria for selecting the design: Embedded mixed-methods

<table>
<thead>
<tr>
<th>Design</th>
<th>Implementation</th>
<th>Priority</th>
<th>Stage of Integration</th>
<th>Theoretical perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embedded mixed methods</td>
<td>Quantitative</td>
<td>Mainly</td>
<td>Interpretation phase</td>
<td>Pragmatic approach (guides the inquiry process)</td>
</tr>
<tr>
<td></td>
<td>followed by</td>
<td>quantitative, qualitative data is embedded</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>qualitative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>followed by</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>quantitative</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Phases of Embedded Mixed Methods Design

Broadly speaking, there are two types of mixing procedures that can be employed in a single research study. Concurrent mixing, occurs in a single phase, is where two methods (quantitative and qualitative) are independent from each other and equal priority is given to both approaches. The second type, sequential mixing, is where either quantitative or qualitative data is collected first, and the results from first phase inform the second form of data collection (Creswell & Plano Clark, 2007). This research used sequential mixing procedures that proceeded in three phases occurring in a sequence: first phase at the beginning of the semester is the quantitative phase, a second qualitative phase occurs during the semester, and the final quantitative phase occurred at the end of semester.
The overall embedded mixed methods design including the three phases employed in this study is illustrated in Figure 4. Each notation used in the figure has a definite meaning that visually represents the overall mixed methods design employed in this study. The use of arrows (→) indicates the sequence in which the methods will occur—quantitative methods will follow qualitative methods that will be followed by another phase of quantitative methods. The notation QUAN (qual) indicates the priority of quantitative methods along with qualitative methods embedded within an overall quantitative design of the study, as indicated by the use of bold letters.

Figure 4. The three phases of the overall embedded mixed methods design of the study including three phases (Adapted from Creswell and Plano Clark, 2007).

In the first phase, the quantitative data was collected and analyzed from implementing two instruments, STEBI-B and the Physical Science Concept test, to preservice elementary science teachers at the beginning of the course. Details about the course and the instruments are provided in the sections to come. The second phase, qualitative, occurred after the first quantitative phase. In this phase the participants were selected and groups were formed based on the initial quantitative results. The three groups of participants, including students with low self-efficacy, medium self-efficacy, and high self-efficacy score, were selected after the analysis of students’ initial STEBI-B responses. In the final quantitative phase, the two instruments were administered as post-
test at the end of the course, followed by statistical analysis of the data. The research questions posed in this study were answered based on the interpretation of both quantitative and qualitative data.

The rationale for this approach, phases to occur in sequence, was that the initial quantitative data collected and analysis guide the process of selecting the participants. This qualitative phase was designed to follow up on the experiences of participants with certain type of outcomes, which are low, medium and high self-efficacy pre-scores, throughout the course. The qualitative phase also intended to illuminate the factors effecting changes in participants’ self-efficacy before and after their exposure in the specialized physics content course. The final stage of quantitative data collection and analysis was important for investigating the second research question focusing on the relationship between participants’ science self-efficacy beliefs and science conceptual understanding.

**Research Context**

This study was conducted in a specialized physics content course at a large mid-western university during two semesters, Spring and Fall 2013. This science content course was specifically designed for early childhood and elementary education majors. The course focused on preparing preservice science teachers to teach basic physical science topics that are well aligned with the K-6 science curriculum. The course content is divided into several smaller units on topics including (1) electricity and magnetism and (2) force and motion. Other goals of the course include enhancing preservice teachers’ inquiry skills by modeling inquiry-based instructional strategies, problem-solving skills, and understanding of the nature of science.
Unlike traditional lecture, this semester-long course is structured as a lecture-laboratory format in a constructivist environment emphasizing scientific inquiry-based investigations, building on team work, and small and large group discussions. Each major unit, for instance electric circuits, was divided into smaller units taught through the 5E learning cycle—Engage, Explore, Explain, Elaborate, Evaluate (Bybee 1997). Unit outlines and instructional activities were made available on the Smart Board as well as BlackBoard site of the course during the class time for students to see on their computer screen.

The course is taught in the Department of Physics and Astronomy. The 5-credit hour course meets thrice a week, two class sessions are of hour and fifty minutes long and the Friday session is of fifty minutes that includes weekly quiz. The maximum enrollment in each of the two sections typically range from 34 to 36. The prospective teachers work in groups of three for developing their own conceptual understanding of physics concepts by conducting simple scientific investigations, presenting their ideas to one another, solving simple numerical problems, and group presentations. A variety of formative and summative assessments running seamlessly within the phases of learning cycle were also a prominent feature of the course.

Population and Sampling

The participants of the study were Early Childhood or Elementary Education majors enrolled in both sections of the specialized physics content course. The preservice teacher participates in this course during his/her sophomore, junior or senior year. Both spring and fall 2013 sections were taught by the same professor – faculty member in the Department of Physics and Astronomy. In spring semester, thirty-two preservice teachers
enrolled in the spring 2013 course, and twenty-five of them volunteered to participate in the study. In fall semester, thirty-four preservice teachers enrolled in the course and twenty-six volunteered to participate in the study.

Institutional review board informed consent forms were distributed to participants who volunteered to take part in this study. Once the participants gave permission, the two instruments STEBI-B and Physical Science Concept Test were administered as pre- and post-test before and after the course intervention. After the analysis of the pre-STEBI-B data, a total of 18 participants including nine preservice teachers from each section per semester were invited to participate in interviews. The interview process is discussed in full details in the next section.

The selection of the participants was based on their pre-self-efficacy scores. The low, medium and high score categories were informed by the participants’ scores, low scores were defined as the lowest quartile followed by medium scores and high scores in the top quartile. The details about the quantitative measures are provided in the subsequent sections. Three participants from each cohort, having low, medium and high self-efficacy scores, were selected. The selected participants were asked for their willingness to take part in interview process and received $10 gift card (Starbucks or Amazon) for their participation. This type of selection allowed researcher to compare common patterns specific to different levels of science self-efficacy beliefs. Furthermore, rich descriptions of participants’ experiences, belonging to either level of self-efficacy initially, provided a better understanding of the factors effecting changes in their self-efficacy beliefs after participating in the content course.
Data Collection

Mixed methods approach relies on both quantitative and qualitative approach for answering the research questions. According to Johnson and Turner (2003) “A method of data collection is a simple technique that is used to collect empirical research data” (p. 298). The data collection strategies are intrinsic to the type of mixed methods design selected for the study (Creswell & Plano Clark, 2007). Table 4 includes the alignment of research questions with the data collection techniques for various research phases.

Table 4

Alignment of research questions with various data sources

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Research Phase</th>
<th>Data collection methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How do preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) change during the specialized physics content course?</td>
<td>Phase 1, 2 and 3</td>
<td>Quantitative sources • Pre-post design STEBI-B (Enochs &amp; Riggs, 1990) Qualitative sources • Pre-post semi-structured interview with target participants - Low self-efficacy (n=6) - High self-efficacy (n=6) • Classroom observations, field-notes • Artifacts (course syllabus, students’ written work)</td>
</tr>
<tr>
<td>1a. Is there a significant change in science self-efficacy (PSTE and STOE) beliefs of preservice elementary teachers participating in the specialized physics content course?</td>
<td>Phase 1 and 3</td>
<td>Quantitative sources Pre-post design STEBI-B (Enochs &amp; Riggs, 1990)</td>
</tr>
</tbody>
</table>

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<th>Research Phase</th>
<th>Data collection methods</th>
</tr>
</thead>
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<td>Phase 1, 2 and 3</td>
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</tr>
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<td>Phase 1 and 3</td>
<td>Quantitative sources Pre-post design STEBI-B (Enochs &amp; Riggs, 1990)</td>
</tr>
</tbody>
</table>
### 1b. What factors associated with the specialized physics content course contribute to changes in preservice elementary teachers’ science self-efficacy (PSTE and STOE) beliefs?

**Phase 2: qualitative only**

**Qualitative sources**
- Pre-post semi-structured interview with target participants
  - Low self-efficacy (n=6)
  - High self-efficacy (n=6)
- Classroom observations, field-notes
- Artifacts (course syllabus, students’ written work)

### 2. What is the relationship between preservice elementary teachers’ science self-efficacy beliefs and science conceptual understanding?

**Phase 1 and 3**

**Quantitative sources**
- Pre-post design-STEBI-B (Enochs & Riggs, 1990)
- Pre-post design-Physical Science Concept test

### 2a. What is the relationship between preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) and conceptual understanding of physics prior to participation in the specialized physics?

**Phase 1 and 3**

**Quantitative Sources**
- Pre STEBI scores
- Pre Physical Science Concept test scores

### 2b. What is the relationship between preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) and conceptual understandings of physics after their participation in the specialized physics content course?

**Phase 1 and 3**

**Quantitative Sources**
- Post STEBI scores
- Post Physical Science Concept test scores

### 2c. What is the relationship between changes in science self-efficacy beliefs (PSTE and STOE) and changes in conceptual understandings of physics?

**Phase 1 and 3**

**Quantitative Sources**
- Gain scores - STEBI-B
- Gain scores – Physical Science Concept test
Quantitative Sources – Instruments

Two instruments, STEBI-B and Physical Science Concept test, were administered as pre- and post-test to the participants of this study. Both the instruments were completed by all the volunteer participants on the first day of the content course. Care was be taken to protect the identity of the participants by designating each student response with a unique identifier. The unique identifier also helped to match the pre- and post-test responses on both tests for each participant.

Science teaching Efficacy Belief Instrument (Enochs & Riggs, 1990)

STEBI-B was developed by Enochs and Riggs (1990) for examining preservice elementary teachers’ science self-efficacy beliefs. It consists of 23 items on a 5-point Likert scale that has choices from ‘strongly agree,’ ‘agree,’ ‘uncertain,’ ‘disagree’ and ‘strongly disagree’. STEBI-B is comprised of two sub-scales: Personal Science Teaching efficacy (PSTE) scale and Science Teaching Outcome Expectancy (STOE) scale. While the PSTE scale measures preservice teachers’ personal beliefs that they can teach effectively in future classrooms, the STOE scale measures preservice teachers’ belief that their teaching will enhance student learning (Bandura, 1997).

There are 13 items that assess PSTE beliefs (e.g., “I will continually finding better ways to teach science” and 10 items that assess STOE beliefs (e.g., “When a student does better than usual in science, it is often because the teacher exerted a little extra effort”). As STEBI-B is a 5-point Likert Scale, the range of score on PSTE scale can vary between 13 and 65 and STOE in between 10 and 50. Thus, higher the score, the more efficacious is the preservice teacher about future science teaching.
Validity and Reliability

In Enochs and Riggs (1990) study, the value of reliability coefficient or Cronbach’s coefficient alpha was found 0.90 for the PSTE scale, and 0.76 for the STOE scale. Since the scale has been created, it has been widely used in a number of research studies examining preservice elementary teachers’ self-efficacy beliefs. Most of these research studies did not cross-validate the validity or reliability of the instrument while implementing it to preservice elementary teacher population (Bleicher, 2004). Bleicher (2004) proposed that re-examination of STEBI-B instrument is necessary due to its extensive use in numerous studies. The reliability coefficient from Bleicher’s (2004) study came out as 0.87 for PSTE and 0.72 for STOE. These values show that both scales are within the internal consistency range of accepted values 0.7 to 0.9. Two items from the STOE scale, 10 and 13, were re-worded based on the factor analysis results. The changes include changing the word from “some students” to “students”, which increased the reliability of the instrument. Several studies have adopted the reworded version of STEBI-B for research purposes (Bleicher, 2004).

On similar lines, this study used the revised version of STEBI-B (See Appendix A). Reliability tests were conducted to determine the Cronbach alpha coefficient for the PSTE and STOE subscales for this study (see Table 5). All values were well above the accepted range of 0.65 (Chandrasegaran, Treagust, & Mocerino, 2007).

Table 5

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSTE</td>
<td>0.80</td>
<td>0.88</td>
</tr>
<tr>
<td>STOE</td>
<td>0.63</td>
<td>0.70</td>
</tr>
</tbody>
</table>
Physical Science Concept Test

Physical Science Concept test was administered as pre- and post-test to the preservice teachers enrolled in specialized physical science content course on the same day as the STEBI-B. The test was administered after the participants completed STEBI-B. The Physical Science Concept test was used to measure the science conceptual understanding of the participants on the concepts covered in the content course. These concepts include: electricity, magnetism, and force and motion. Some of the sub-topics on electricity include: understanding how a bulb operates in a circuit, simple circuits including series, parallel and combination of the two, circuit elements, and Ohm’s law and its application in various circuits. Some of the topics covered in magnetism include how magnets work, poles of a magnet and Earth’s magnetism. Some of the topics covered in force and motion include understanding balanced and unbalanced forces, friction, uniform motion, motion diagrams, and acceleration. Appendix B illustrates important concepts covered in the course, which also served as a starting point in identifying the instrument items well aligned with the concepts.

The Physical Science Concept Test consists of 15 multiple choice items in total. The test includes items on electricity and magnetism and force and motion to assess participants’ conceptual understanding on most, if not all, of the science concepts covered in the course. The choices range from four to five depending on the number of distractors. There is one correct answer for each question. The first page covers detailed instructions for the test along with key to the symbols (e.g., symbol of a bulb or resistor) used in the items. Since the test is designed to assess science conceptual understanding,
participants do not need any other device while working on the test such as calculator or a computer software.

**Building the Physical Science Concept test**

For selecting the items for the Physical Science Concept test items for the science concept test, I reviewed research-based instruments in physics that addressed topics electricity, magnetism, and forces and motion. Concept inventories serve as valuable tools for assessing student learning, validating instructional strategies and curricular innovations (Gary, Evans, Cornwell, Costanzo, & Self, 2003). The purpose of using these inventories vary from identifying misconceptions to bringing subsequent reform in teaching strategies, methods of instruction, and curriculum. While these inventories are widely being used by practitioners as well as researchers in high school and college physics classrooms, following criteria were used to select the items from existing instruments for building the Physical Science Concept test-Version A.

**Criteria for selecting instruments**

First, the assessments should align with the learning goals of the course. The content taught in the course covers several topics on electricity, magnetism and force and motion. Second, the instruments from which the items are selected should be valid, reliable and have potential to be adapted for preservice elementary teachers. Third, assessments should assess conceptual understanding of the science concept and not problem solving skills. Lastly, the instrument should be accessible in terms of administration, analysis and interpretation. Based on the above criteria, items were selected from three instruments. These instruments have been summarized in Table 6,
which includes topic addressed, format of the test and the intended audience the authors of the test suggest.

Determining and Interpreting Resistive Electric Circuit Concepts Test-DIRECT (Engelhardt & Beichner, 2004) was developed to understand college students’ difficulties and misconceptions regarding direct current resistive electric circuits. Content validity was established by giving the test to an expert panel for which helped to revise the questions. Reliability was determined by calculating the Kuder-Richardson formula 20 (KR-20), which was found to be 0.71 for version 1.0 and 0.70 for version 1.1. Version 1.0 is helpful for understanding conceptual understanding of students as it is more qualitative whereas version 1.1 focusses on mathematical skills as it is more quantitative. Version 1.2 is also available, which contains most of the items from version 1.1.

Force Concept Inventory-FCI (Hestenes, Wells & Swackhamer, 1992) is designed to understand introductory physics students’ beliefs and misconceptions of Newtonian concepts of force. The FCI is an improved version of the Mechanics Diagnostic Test (Halloun & Hestenes, 1985). Reliability of the test was established by statistical techniques, Kuder-Richardson (KR) reliability coefficient was 0.86 for the pre-test and 0.89 for the post-test, which indicate that the test is highly reliable. The inventory can be used in high school, college, and university courses to not only assess student understanding of the force concepts, but also to evaluate effectiveness of instruction and curriculum (Hestenes and Halloun, 1995).

The NSTA PD Indexer tool (Byers, Koba, Sherman, Scheppke & Bolus, 2011) is an Electronic professional development (e-PD) online portal is designed by National Science Teachers Association (NSTA). Specifically, My PD Indexer tool helps educators
to evaluate their own science content knowledge and identify gaps in their understanding of the specific science topic. The tool could also be used as pre-test and post-test for examining gains in the content knowledge. There were four stages to create the items for each science area and to establish validity and reliability of these items. During stage 1, the draft multiple-choice assessment items were developed by item developers, which were selected based on their prior work as members of the NSTA. These items were further reviewed by PD Indexer team and later by the experts in the science content area. After subsequent revisions, the items were posted to the NSTA’s online assessment system and pilot tested by administering to group of NSTA members. Reliability was established by calculating Cronbach $\alpha$, which came out as 0.82, indicating that the test is reliable. The PD Indexer tool could be used to diagnose K-8 teachers’ science content knowledge to identify gaps in the understanding of specific science content area.

Table 6

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Topic addressed</th>
<th>Format</th>
<th>Audience</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT</td>
<td>Electric circuits</td>
<td>29 Multiple choice questions</td>
<td>High school and university students</td>
</tr>
<tr>
<td>FCI</td>
<td>Force and motion</td>
<td>29 multiple choice questions</td>
<td>High school, college and university</td>
</tr>
<tr>
<td>The NSTA PD Indexer</td>
<td>Electric and magnetic forces, force</td>
<td>10 multiple choice questions</td>
<td>K-8 science teachers</td>
</tr>
<tr>
<td>tool</td>
<td>and motion, energy, etc.</td>
<td>in each sub topic</td>
<td></td>
</tr>
</tbody>
</table>

Item Selection for Physical Science Concept Test - Content Validity

Validity of a test is regarded as the fundamental characteristic of any test (Osterlind, 2006). Both content and construct validity of the test was established. Content validity provides information on whether the content of the assessment is appropriate to
measure content knowledge of the population it intends to measure. The content appropriateness was central to the development of the Physical Science Concept Test as it is intended for preservice elementary science teachers participating in the course whose content is well-aligned with K-6 science curriculum. To start with, a spreadsheet was created that contain main concepts covered within the course and the assessment goals. 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 alignment is shown in table 7 (See Appendix C for full chart).

Table 7

*Example of concepts aligned with assessment goals*

<table>
<thead>
<tr>
<th>Topic</th>
<th>Concept (Sub-concept)</th>
<th>Assessment goals</th>
<th>Selected from DIRECT 1.2 (# represents test item)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>Conservation of charges in a bulb and complete circuit:</td>
<td>Understand and apply the concept of conservation of charge in a light bulb and other circuits</td>
<td>Q 10</td>
</tr>
<tr>
<td></td>
<td>(1) Understand the contact points of the bulb, how the charges flow in the bulb</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Understand the concept of complete circuit in order to light the bulb</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) Understand the conservation of charge in a variety of circuits</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4) Understand how switch works (contact points)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(5) Understand how switch can be used in the circuit to turn bulb on and off</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Understand and apply the knowledge of how a bulb works (two-contact points) in a complete circuit</td>
<td>Q 8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apply the knowledge of how switch is used to open or close a circuit or in a single path.</td>
<td>Q 18</td>
</tr>
</tbody>
</table>

After several iterations of checking and re-checking of the table, 20 items were finalized for the Physical Science Concept Test-Version A. The face and content validity
was established by sending the list of 20 items, along with the assessment goals, to an expert panel (See Appendix D for the sample questions formatted to get feedback). The expert panel comprised of 2 professors from physics, 3 professors from science education, one professor from nuclear engineering, 3 PhD students from physics, and 2 science education graduate students. The panel provided feedback on whether item is aligned with the assessment goal by choosing agree, disagree or making comments and suggestions. The items of low agreement between reviewers were revised or reworded None of the items were removed for Version A as there was no consensus on removing a single item as suggested by the reviewers’ feedback file.

The test was administered to 110 college students. The student responses on the Scantron sheet were imported into Excel file for further analysis as described below.

**Construct Validity (Pilot-test of the instrument)**

Construct validity provides information of the extent to which the test measures the theory or trait it intended to measure (Osterlind, 2006). The construct validity was established by factor analysis using Classical Test Theory (CTT). According to Osterlind (2006), “CTT provides a theory and associated psychometric methods to bring our measurement as close to the goal as possible” (p. 54). This measurement theory pertains to its ontological assumption that there exists an absolute reality that can be known. Osterlind (2006, p. 75) summarized the common underlying assumptions of CTT as:

1) The expected score is true score, zero on a scale.

2) The correlation between true score and error score is zero on a scale.

3) The correlation between error score on one measure and true score on another parallel measure is zero on a scale.
4) The correlation between errors on distinct measures is zero on a scale.

5) The expected mean (average) error on a test is zero on a scale.

**Factor Analysis**

Factor analysis was performed to test two things (1) whether the specific factors are influencing the test responses in the desired way, and (2) how are these factors related to the responses (Decoster, 1998). First, the TESTFACT software was used for Full Information Factor Analysis (FIFA). The FIFA provides information on internal structure of the test or in other words dimensionality associated with the test (Osterlind, 2006). The test measures one component, physical science conceptual understanding, and thus is one-dimensional in nature. This analysis was conducted with the assumption of one factor, physical science conceptual understanding, and provide details on strength of factor loading for each item (See Appendix E). The values found for some items, for example item 15 shows value as 0.15 were low and indicated that the factor is weakly loaded. Such items with low values on FIFA were discarded.

**Item Difficulty Index**

The item difficulty index illustrates the difficulty level of test items. It represents the percentage of students who answered a particular item correctly. The TESTFACT software shows this index as ‘item facility’ (Osterlind, 2006). The value of the facility index, indicated by $p$ value, could range from 0 to 1, with 0.5 being the most appropriate value. The values of facility index of items vary between the range of 0.04 to 0.65 (See Appendix E). The averaged value is 0.41, which lies in the acceptable range of 0.3 to 0.9. The items that have facility index value below 0.3 suggest that less number of students got the item right. For example, item 1 (value 0.08) has value less than 0.3 but is not
necessarily an inadequate test item, but could be appropriately challenging for the population sampled. The decision of whether or not items with lower facility index (less than 0.3) should be retained for final test version was taken by careful examination of the item values on other test measures. After reconsidering the items that had low item facility index (< 0.3), item 10 (value 0.04) was deleted as it showed the lowest value for item facility index indicating unsatisfactory test item for the final test version.

**Point Biserial Coefficient** ($r_{pbis}$)

The point bi-serial correlation coefficient value determines the measure called item discrimination. This indicates students’ “performance on an item in relation to the overall ability or proficiency (Osterlind, 2006). The more positive point-biserial value indicates that the students who score high on the overall test are getting the item right. The widely used accepted value for point biserial coefficient is $r_{pbis} \geq 0.2$ (Varma, 2006). It was observed that similar items had multiple problems with reference to the widely accepted values for different test measures (for instance Q15 has $r_{pbis} = 0.27$, low FIFA index is 0.15) and thus, were not selected for the final version of the test (See Appendix E for all values).

**Reliability Coefficient (Cronbach’s $\alpha$)**

In reference to the Classical Test Theory, reliability of the test is defined by “consistency of measurement when assessment is repeated for an individual or for groups of a population” (Osterlind, 2006, p. 119). The reliability of Version A of the test was determined by using SPSS reliability function that provides internal consistency of the test by Cronbach’s $\alpha$ value. This value came out as 0.5 which is not above the accepted range for multiple choice item test (Nunnally & Bernstein, 1994).
After the item analysis was completed, 5 items were discarded leaving a total of 15-item for the Physical Science Concept Test-Version B (Appendix F). The final version of the test administered to 47 college students. The reliability of this version was calculated using SPSS software. The Cronbach’s α value for this version came out as 0.66 (Appendix G). The value above 0.65 is acceptable for group assessments (Chandrasegaran, Treagust, & Mocerino, 2007, Nunnally & Bernstein, 1994).

**Qualitative sources**

The qualitative data were collected during the second phase of the research study, which followed immediately after the first quantitative phase. The purpose of the second phase of the research study was to examine participants’ self-perceptions of their science teaching self-efficacy during their participation in the physical science content course, and the factors that may produce strongest effects on these beliefs. Therefore, the second phase addressed research question 1 and 1b. The sources included observations, semi-structured interviews with 18 participants, and artifacts. While observations and artifacts provided the holistic picture of the whole class group, selected participants’ interviews provided an in-depth information on how participants interpret changes in their own science self-efficacy beliefs in relation to the specialized science content course. Each data source is now being discussed in detail.

**Interviews**

Interviews are useful to understand the participants’ perceptions and beliefs about the phenomena or the world around them (Hatch, 2002). Researchers widely use interviews to uncover underlying meanings and patterns of behavior (Lincoln & Guba,
1985) through participants’ voices. Interviews are particularly useful as they “provide avenues into events and experiences” (Hatch, 2002) that happened back in time as well as those that have not been captured via observations. Moreover, interviews also provide significance of artifacts collected and how these artifacts contribute to construct meanings that participants’ collectively make from the experiences within the context (Hatch, 2002).

On the other hand, interviews have limitations in that they may not provide full information of “what is in and on someone else’s mind” (Patton, 1990, p. 278). They are also limited by researcher’s lack of time, researchers’ ability to conduct them in order to draw all the relevant information from interviewee, and unfamiliarity with the participant, which may sometimes restrict individuals to open up all that is in the mind. Its limitations can also be tied to its reliability as researchers rely on what is being told and take for granted that the information provided is true to the best. Building rapport with the participant, explaining the clear purpose of interview prior to the interview process and selecting appropriate place to ensure privacy of the information and recording of the voice with minimal disturbance around will help to overcome some of the limitations (Hatch, 2002). Also, collecting interview data in parallel with other sources enhance understanding of the phenomena being explored, which in the case of this study is science self-efficacy beliefs, its relationship with science conceptual understandings, and the course factors that may affect participants’ science self-efficacy beliefs.

For the purposes of this study, semi-structured interviews were conducted with preservice elementary science teachers who gave consent to participate in the interview process. An interview protocol was developed that consisted of questions with increasing
complexity to understand participants’ beliefs on science self-efficacy beliefs and how these are influenced by the constructivist environment of the course. These questions have been chosen from existing literature on factors that influence science self-efficacy beliefs in various stages of the teacher preparation program.

Semi-structured interview process was selected for this study because it allows researchers flexibility of “probing into areas that arise during interview interaction” (Hatch, 2002). A total of 18 preservice teachers were chosen for the two interviews—one conducted within a few weeks after the semester started and the other few weeks before the semester concluded. The purpose of the initial interview was to gain insight into participants’ science experiences prior to college science coursework that may have an impact on their initial science self-efficacy beliefs (See Appendix H for interview questions). The purpose of the second interview was to gather information on how participants’ express their own science self-efficacy beliefs, how course experiences influenced these beliefs, and their own evaluation on their confidence to teach science after participating in the science content course (See Appendix I for interview questions). Both interviews were conducted with the same participants. The initial interview lasted for about 35-40 minutes, and the second interview lasted for about an hour or more depending on participants’ willingness to share details on the questions posed to them. All interviews were conducted individually with a single participant and were audio-recorded by the researcher. This was followed by transcribing the interview data and maintaining separate file for each participant.
Observations

The main goal of observations is to understand the social phenomena being explored from the participants’ perspective within a particular context (Hatch, 2002). Patton identifies observations as a powerful source as it provides firsthand experience to researcher to understand participants’ views and how things operate within the setting (Patton, 1990).

In this study, the observations occurred in the two sections of the specialized content course. The two sections met thrice a week on alternative days for 16 weeks. Each course meeting is scheduled for an hour and 50 minutes with an exception on Friday where class meets for 50 minutes. Observation data were collected twice a week in an hour and fifty minute class session for first 8 weeks and then once a week for the next 8 weeks for both Spring and Fall 2013 semester.

According to Hatch (2002), it is important to understand the role that researcher plays while conducting observations such as level of involvement and strategies employed to collect these observations. The goal of observations was to capture the events and its description via field notes, thus researcher did not participate in the classroom activities. These field notes were taken by researcher from the back of the room to avoid any interference or distraction of students in the classroom. The participants selected for interview process were observed more closely as compared to other students, but observations were extended to gain understanding as a whole class context.

The field notes taken were recorded in a format suggested by Corsaro (1981; 1985) classification including: 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 literature read), and
personal notes (contextual factors that may influence while taking observations). This
type of classification helped to keep track of all details involved with the observations
process and helped to organize the data for further analysis.

**Data Analysis**

Data analysis proceeded in three distinct stages. During the first stage, part of the
quantitative analysis was done immediately after the STEBI-B survey was implemented
as pre-test. This analysis allowed selection of the participants for collecting qualitative
data. The other two stages of analysis occurred at the end of data collection. In the second
stage, qualitative data was analyzed followed by the analysis of the quantitative data in
the third stage. The alignment of research questions with the data analysis techniques is
illustrated in the Table 8. Each of the stages is then described in detail.

Table 8

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Stages</th>
<th>Data analysis techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How do preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) change during the specialized physics content course?</td>
<td>Stage 1: Quantitative analysis Stage 2: Qualitative analysis</td>
<td>-Statistical analysis of the quantitative data including&lt;br&gt;• Descriptive analysis&lt;br&gt;• Repeated measures multiple analysis of variance-MANOVA&lt;br&gt;• Cohen’s D&lt;br&gt;-For Qualitative Data&lt;br&gt;Grounded theory&lt;br&gt;• Open coding: Drawing coded&lt;br&gt;• Axial coding: Patterns and themes&lt;br&gt;• Theoretical Comparison: Comparing data within categories as well as existing literature</td>
</tr>
<tr>
<td>Question</td>
<td>Stage 1: Quantitative analysis</td>
<td>Stage 2: qualitative only</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
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<td>--------------------------</td>
</tr>
<tr>
<td>1a. Is there a significant change in science self-efficacy (PSTE and STOE) beliefs of preservice elementary teachers participating in the specialized physics content course?</td>
<td>Correlation Analysis</td>
<td>Grounded theory</td>
</tr>
<tr>
<td></td>
<td>Partial correlation controlling for time</td>
<td></td>
</tr>
<tr>
<td>1b. What factors associated with the specialized physics content course contribute to changes in preservice elementary teachers’ science self-efficacy (PSTE and STOE) beliefs?</td>
<td>Correlation Analysis</td>
<td>Grounded theory</td>
</tr>
<tr>
<td></td>
<td>Partial correlation controlling for time</td>
<td></td>
</tr>
<tr>
<td>2. What is the relationship between preservice elementary teachers’ science self-efficacy beliefs and science conceptual understanding?</td>
<td>Correlation Analysis</td>
<td>Grounded theory</td>
</tr>
<tr>
<td></td>
<td>Partial correlation controlling for time</td>
<td></td>
</tr>
<tr>
<td>2a. What is the relationship between preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) and conceptual understanding of physics prior to participation in the specialized physics?</td>
<td>Correlation Analysis</td>
<td>Grounded theory</td>
</tr>
<tr>
<td></td>
<td>Partial correlation controlling for time</td>
<td></td>
</tr>
<tr>
<td>2b. What is the relationship between preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) and conceptual understandings of physics after their participation in the specialized physics content course?</td>
<td>Correlation Analysis</td>
<td>Grounded theory</td>
</tr>
<tr>
<td></td>
<td>Partial correlation controlling for time</td>
<td></td>
</tr>
<tr>
<td>2c. What is the relationship between changes in science self-efficacy beliefs (PSTE and STOE) and changes in conceptual understandings of physics?</td>
<td>Correlation Analysis</td>
<td>Grounded theory</td>
</tr>
<tr>
<td></td>
<td>Partial correlation controlling for time</td>
<td></td>
</tr>
</tbody>
</table>
Stage 1-Quantitative Analysis

During this stage quantitative analysis of the data, collected from administration of the STEBI-B and the Physical Science Concept test as pre-test, was conducted. First, the raw data from all participants’ taking pre-STEBI-B was imported in the EXCEL sheet. Using IBM Statistical Package of Social Science (SPSS) software (Version 19.0 for Windows 7), reliability analysis was conducted (n=51) to obtain the Cronbach’s Alpha coefficient for both pre- and post-PSTE and STOE as well as pre- and post- Physical Science Concept Test. For this study, the Cronbach’s Alpha coefficient for pre-PSTE was found to be 0.80 and pre-STOE was 0.63. The Cronbach’s Alpha coefficient for post-PSTE was found to be 0.88 and post-STOE was found to be 0.70. These values are comparable to the values from Enochs. and Riggs (1990), 0.90 for the PSTE and 0.76 for the STOE scale. The pre- and post-Physical Science Concept Test reliability was 0.60 and 0.70 respectively.

Next, the data was analyzed to obtain the score of each participant on both scales, PSTE and STOE. Once the total score of each participant is identified, the participants will be listed in the order from lowest to highest scores. Post-hoc analysis of the data will help in obtaining maximum variation and determining which scores represent low, medium, and high science self-efficacy beliefs. Because of the clear differences between the participants’ pre-PSTE scores as compared to pre-STOE scores, the PSTE scale was used to select three participants for each group: low, medium and high. The participants scoring in the 80\textsuperscript{th} percentile or above were represented as the high science self-efficacy group. The participants whose scores were in the 70\textsuperscript{th} or above were represented as the medium group and the participants scoring in the 60\textsuperscript{th} percentile or lower became part of
the low science self-efficacy group. Out of two groups formed, three participants were chosen from each group (from each semester) to participate in qualitative data collection processes. Thus, nine participants were chose each semester making a total of 18 participants to participate in the interviews.

Stage 2-Qualitative Analysis

Second stage of analysis involved analysis of the qualitative data collected to inform research question 1 and 1b. In this study, interviews serve as the primary source of the data followed by secondary sources that are observations and artifacts. Grounded theory approach (Strauss & Corbin, 1988) was used to analyze qualitative data. As explained by Strauss and Corbin (1988), “theory” is conceptualized as set of themes or categories developed through rigorous and systematic analysis to explain the phenomena being investigated. According to Strauss and Corbin (1988), grounded theory techniques “allow theory to emerge from the data, are likely to offer insight, enhance understanding, and provide a meaningful guide to action” (p. 12). Grounded theory approach is most suited for this study as the analysis process offers flexibility of allowing the themes to emerge from data, rather than starting with pre-existing categories. This process also allowed adding new knowledge to the existing literature on factors that influence science self-efficacy beliefs of preservice elementary science teachers in a science content course as well as having enhanced understanding of how changes occur in preservice teachers’ self-efficacy beliefs during the course. The following paragraph describes the process of analysis for the interview data followed by analysis of observations and artifacts.

The analysis started with an open coding of the interview data. First, each participant’s pre- and post- interview data was transcribed and stored as a separate file as
raw data along with the details such as interview time, date and place. The raw data was read and re-read for common characteristic, factor or event as described by participants to assign initial codes representing these commonalities in the data. Second, initial codes were grouped to generate categories or themes. Some categories also had a sub-category or multiple sub-categories under it. All recordings of the initial codes, emergent themes along with small descriptions of each theme and its location in the interview transcripts or observation records were maintained in the EXCEL sheet in various color codes.

To ensure the trustworthiness of the themes that emerged from the data, an expert in qualitative analysis, major advisor, was consulted to cross check on emergent themes from the data. One transcript, randomly picked, was also reviewed independently to identify emergent themes. Once all of the interview data were analyzed by open coding, the process of axial coding was utilized. Axial coding is essential because it allows reassembling of the data that were fractured during open coding” (Strauss & Corbin, 1988, p. 124). Each category and sub-categories were re-visited to draw meaningful links between them. This crosscutting technique was helpful to find meaningful patterns that are explanations for understanding the phenomena rather than singled out terms and events. This process of creating relational statements (Strauss & Corbin, 1988) was continued until saturation was reached. According to Strauss & Corbin (1988), a category was considered to be saturated once no new categories or links are emerging from the data.

The final analysis step was done by the theoretical comparison method, which is similar to constant comparison method. 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 will be made based on prior knowledge and the existing literature.

The analysis of the observation data were similar to the analysis of the interviews. The field notes, classified according to Corsaro’s (1981; 1985) format explained earlier, was further expanded for identifying emergent themes. The themes generated from interview and observations were further used in triangulating the findings for deeper understanding of the complex phenomenon being explored in the study.

**Stage 3-Quantitative Analysis**

This stage of analysis occurred at the end of the data collection process. Specifically, at this stage the data analysis was conducted after the administration of post- STEBI-B and post-Physical Science Concept test to all participants (N=51) at the end of the semester. Both the STEBI-B and the Physical Science Concept test data were analyzed using IBM SPSS. The results of research question 1 (mainly 1a) were draw upon by statistical analysis by comparing the means from STEBI-B pre- and post-test through descriptive analysis, multivariate analysis of variance (MANOVA) and Cohen’s D. The results of research question 2 utilized correlational analysis for examining the relationship between preservice elementary teachers’ science self-efficacy beliefs and science conceptual understandings.

**Descriptive Analysis**

According to Kleinbaum, Kupper, Nizam and Muller (2008), descriptive statistics helps to provide quantitative summary of the data set “designed to describe a particular aspect or characteristic of the data set” (p. 15). The two measures employed were measures of central tendency and of variability. The central tendency provide a single
value or average of all the data being measured. For the variability, sample variance and the standard deviation was computed. The descriptive statistics is helpful to see some patterns in the data; however, it does not give complete information about all the features of the data set (Kleinbaum et al., 2008).

**Repeated Measures MANOVA**

A pre-post repeated measures multivariate analysis of variance (MANOVA) design was used to evaluate the significant difference between two set of items (Warner, 2008), which is pre- and post- STEBI-B scores. The $F$ statistics calculated from Wilks’s lambda was used to test the significant differences between the mean vectors across time. The multivariate null hypothesis was that there is no significant differences between the pre- and post-self-efficacy mean scores over time (from beginning to the end of the semester). The MANOVA design was suitable approach for this study as it allows examining several dependent variables (outcomes) at the same time (Field, 2009; O’Brien & Kaiser, 1985). The MANOVA design also has advantage over separate ANOVAs because of the power to detect an effect due to combination of variables instead of determining the effect of a single variable (as in ANOVA) (Field, 2009; O’Brien & Kaiser, 1985). There exists a statistical significant difference between two groups if the $p$ value is less than .05.

**Assumptions**

There are few underlying assumptions for the use of MANOVA design. First, the data should be normally distributed, which assures that the dependent variables together are normally distributed within groups (Field, 2009). This assumption is fairly true for large samples such as this research study (N=51). The normal distribution was assessed
by a normal probability plot to find whether the data fits to a normal bell shaped curve. SPSS has an option to plot histogram with normal curve, which was used for checking normality of the data. Second assumption is that each score should be independent of all other scores and each measurement is independent of prior measurement. The third assumption is homogeneity of variance, which implies that the variance of the data remains same throughout the data set, which was checked by choosing the option of Levene test in SPSS software. The fourth assumption is that sample data is continuous. Before the beginning of analysis, all the assumptions of the data from STEBI-B were tested via SPSS to meet the requirements for conducting MANOVA.

**Effect Size**

The effect size is the estimate of the magnitude of the effect and provided information about how strongly the two or more variables are related or how large is the difference between groups. For this study, partial eta squared ($\eta^2$) was used as a measure of effect size for MANOVA. By definition, partial $\eta^2$ is the ratio of variance accounted for by an effect. The estimated of effect size (partial $\eta^2$) was computed by using IBM SPSS. The values obtained showed the practical significance of each variable, indicating the amount of variance explained by PSTE, STOE and Content. According to Levine & Hullett (2002), it is important to note that the partial $\eta^2$ values are not additive (unlike eta squared where sum cannot exceed 1.00), and may sum to value above 1.00.

Researchers in the field of statistics have point out that calculation of partial $\eta^2$ could be confusing, especially with the labelling error produced by some of the versions of SPSS (Richardson, 2012). Another debate in the statistics field is on the benchmarks for interpreting partial $\eta^2$ suggested by Cohen (1988) as small = 0.01, medium = 0.06,
large = 0.14. Richardson (2012) claim that problem with interpreting the magnitude according to the suggested norm is that the figures are rounded to only two decimal places. Other problem with interpreting partial $\eta^2$ values is the risk of overestimation of the effects (Levine & Hullett, 2002). Thus, Cohen’s D was also computed for each variable and provided information about the magnitude of the change from pre- to post.

Cohen’s D

Cohen’s D measures the effect size estimate computed by difference in the mean of two groups divided by the pooled estimate of standard deviation (Romano et al., 2006). Since the effect size index is the representation of the difference in sample means in standard deviation units, an effect size of 0.0 indicate that the mean of the post-STEBI scores (after intervention) is at the 50$^{th}$ percentile of the mean of the pre-STEBI scores (before intervention). The measure of Cohen’s D in SPSS supplement the results obtained from MANOVA. While MANOVA design provides whether or not there is statistical difference between two sets of data, effect size adds substantive meaning to the results by measuring the strength of the phenomena being measured. In this study the use of Cohen’s D provided estimation on the effect that participation in science content course activities can have on the preservice teachers’ science self-efficacy beliefs.

Research Question 2

Research question 2 explores the relationship between preservice teachers’ science self-efficacy beliefs and science conceptual understanding during a specialized physics content course. The sub-questions 2a, 2b, and 2c will be explored first to provide complete understanding of the relationship between science self-efficacy beliefs and science conceptual understanding. All the sub-questions will draw upon quantitative
analysis only. The analysis will be carried out in three steps. First, the pre- STEBI-B scores and pre- Physical Science Concept test data will be analyzed by conducting correlational analysis (research question 2a). Second, correlational analysis will be conducted for analyzing post- STEBI-B and post- Physical Science concept test scores. Third, correlational analysis and partial correlation tests will be conducted on gain scores obtained from both sets of data from the two tests.

**Correlational Analysis**

Correlation measures the statistical relationship between the two data sets or is an “index of linear association between two variables” (Kleinbaum et al., 2008), which are independent and normally distributed. For this study, correlation analysis investigated the relationship between science self-efficacy beliefs and science conceptual understanding of preservice teachers. For obtaining correlation between the two sets of data, Pearson product-moment correlation coefficient or $r$ was calculated by using SPSS. It follows that more positive the value of $r$, the more positive will be the association between two variables or data sets. Research question 2a and 2b explored the relationship between two sets: pre-test from both tests and post-test from both tests.

**Partial Correlation**

Partial correlation coefficient describes the “linear relationship between two variables while controlling the effects of other variables” (Kleinbaum et al., 2008). For this study, the relationship between gains scores of STEBI-B and Physical Science Concept test were determined while controlling for time. This was computed via selecting the option for calculation of partial correlation in SPSS software.
CHAPTER 4
RESULTS

Introduction

The purpose of this chapter is to document the results of this research study. The purpose of this study was two-fold. First, the study explored the changes in preservice teachers’ science self-efficacy beliefs (PSTE and STOE) during their participation in the specialized content course. The changes in preservice teachers’ science self-efficacy beliefs on both scales – Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE) were examined both quantitatively and qualitatively (Research Question 1). In addition to exploring changes in self-efficacy beliefs, the purpose of this phase was to examine the relationship between preservice teachers’ self-efficacy beliefs (PSTE and STOE) and science conceptual understanding prior to and after their participation in the specialized content course (Research Question 2).

In this chapter, each research question is restated and relevant findings are presented. Both qualitative and quantitative findings are organized according to the research questions that guided this investigation. The chapter is divided into three distinct parts. The quantitative and qualitative findings associated with the first research question are presented in separate sections, one followed by the other. The first section discusses the quantitative results, followed by the second section that discusses qualitative results pertaining to first research question. The third section discusses quantitative findings pertaining to second research question.
Research Question 1 and Sub-Question

Question 1

How do preservice elementary teachers’ science self-efficacy beliefs (personal science teaching self-efficacy-PSTE beliefs and science teaching outcome expectancy-STOE) change during a specialized physics content course?

Question 1a

Is there a significant change in science self-efficacy (PSTE and STOE) beliefs of preservice elementary teachers participating in the specialized physics content course?

Quantitative Results

The quantitative data were collected from 51 participants who participated in the pre-and post-surveys: STEBI-B and Physical Science Content Test. During statistical analysis, the two scales of STEBI-B (PSTE and STOE) were considered independent of each other. The descriptive statistics for the data are shown in Table 1. Means and standard deviations for the pre- and post-scores on the STEBI-B (both scales) and the Physical Science Content Test are presented. The data from surveys were tested for the normality of distribution of scores on each of the variables. As shown in Table 9, the data were acceptable in terms of skewness (< +/−2.0) and kurtosis (< +/−2.0).

In this group of 51 students, there was an increase in mean PSTE scores from pre-test ($M =44.76 \text{ (SD} =6.19)$) to post-test ($M =51.80 \text{ (SD} =6.03)$). For the same group, there was an increase in mean STOE score (pre $M =34.67 \text{ (SD} =3.66)$, post $M =36.78 \text{ (SD} =3.81)$), and mean content score (pre $M =5.98 \text{ (SD} =2.44)$, post $M =9.19 \text{ (SD} =2.74)$). Although the study did not explicitly focus on testing participants’ content gains, the decision to include content scores in the analysis was based on two reasons. First, the
inclusion of content scores reduces the Type 1 error in the overall analysis. Second, research question 2 includes correlations analysis between content gains and self-efficacy gains, so the content gains are part of the analysis. A repeated measures multiple analysis of variance (MANOVA) design and post-hoc univariate tests, reported below, were performed to determine if significant differences existed among the variables from pre-test to post-test.

Table 9

*Descriptive statistics on variables for self-efficacy and conceptual understanding*

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

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

Repeate Measures MANOVA

The Wilks’ lambda multivariate statistics, similar to F-values in single outcome variable analysis, was used to test whether the differences observed were statistically significant (Table 10). Multivariate tests showed significant difference between the mean vectors across time [$\Lambda = .281$, $F (3, 48) = 40.193$, $p << 0.001$, $\eta^2 = .719$]. Given the significance of the overall multivariate test, univariate tests were performed, described below.
Table 10

*Multiple Analysis of Variance (N=51)*

<table>
<thead>
<tr>
<th>Within Subjects Effect</th>
<th>Value.</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Wilk’s Lambda</td>
<td></td>
<td>40.913a</td>
<td>3.000</td>
<td>48.000</td>
<td>.000</td>
<td>.719</td>
</tr>
</tbody>
</table>

Within Subjects design: Time, a. Exact statistics, b. Computed using $\alpha = .05$

Univariate tests showed significant changes in all the three variables: PSTE, STOE and Content, which based on the pre-post analysis (Table 11). To reduce the probability of the Type I error, using the criterion of $\alpha = .05$, the alpha value (0.5) was divided by 3 (3 tests) that yielded the corrected $p$-value for this data as $p < .0167$. Mean PSTE increased significantly from 44.76 to 51.80 [$F (1, 50) = 95.295, p = 0.000 << 0.0167, \eta^2 = .656$], and mean STOE increased significantly from 34.67 to 36.78 [$F (1, 50) = 10.795, p = 0.002 < 0.0167, \eta^2 = .178$]. The mean content score increased significantly from 5.98 to 9.19 [$F = (1, 50), p = 0.000 << 0.0167, \eta^2 = .587$].

**Effect Size**

Partial $\eta^2$ was used to evaluate the practical significance of each variable, indicating the amount of variance explained by PSTE, STOE and Content. Suggested norms for interpreting partial $\eta^2$ were used to interpret the magnitude of the effect: small = 0.01, medium = 0.06, large = 0.14 (Cohen, 1988). The practical significance effects, as suggested by the partial eta squared values, was higher in PSTE as compared to STOE, explaining 65.6% of the within subjects variance accounted for by PSTE and only 17.8% of the variance accounted for by STOE. Similarly, the partial $\eta^2$ values indicated 58.7% of the variance accounted for by Content.
Researchers working in statistics have recently reported issues on using partial $\eta^2$ as an estimate of effect size, especially in a multifactor ANOVA. They argue that partial $\eta^2$ may not be interpreted as a measure of unique variation in the variable as it accounts for some of the non-error variation by other factors in the analysis (Pierce, Block & Aguinis, 2004; Levine & Hullett, 2002). Because calculation of partial $\eta^2$ may induce the risk of overestimation of the effects (Levine & Hullett, 2002), Cohen’s D was also calculated.

An analysis for the effect size, calculated as Cohen’s D, was conducted for each variable to gain information about the magnitude of the change from pre to post testing (see Table 12). Effect size of the changes observed on the PSTE scale ($d = 1.24$) were relatively higher than the STOE scale ($d = 0.57$). While changes in PSTE showed large effect, the changes in STOE were moderate. The changes in Content ($d = 1.15$) also showed high effect sizes, revealing large effect on changes from pre to post testing.

### Table 11

**Univariate Tests for All Measures**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
<th>Observed Power¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSTE</td>
<td>1263.539</td>
<td>1</td>
<td>1263.539</td>
<td>95.295</td>
<td>.000</td>
<td>.656</td>
<td>1.000</td>
</tr>
<tr>
<td>STOE</td>
<td>114.353</td>
<td>1</td>
<td>114.353</td>
<td>10.795</td>
<td>.002</td>
<td>.178</td>
<td>0.897</td>
</tr>
<tr>
<td>Content</td>
<td>263.686</td>
<td>1</td>
<td>263.686</td>
<td>71.146</td>
<td>.000</td>
<td>.587</td>
<td>1.000</td>
</tr>
</tbody>
</table>

¹. Computed using $\alpha = .05$

### Table 12

**Cohen’s D Effect Size**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Cohen D</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSTE scale (pre-post)</td>
<td>1.24</td>
<td>&gt;0.8. Large effect</td>
</tr>
<tr>
<td>STOE scale (pre-post)</td>
<td>0.57</td>
<td>&gt;0.5. Medium effect</td>
</tr>
</tbody>
</table>
Quantitative gains of the Selected Sample

While the quantitative results presented above provided evidence for participants’ (N=51) gains in science self-efficacy beliefs as a whole group, the section to follow focuses on few selected participants with varied initial levels of self-efficacy beliefs. Eighteen participants were selected after the administration of STEBI-B pretest survey. The participants belonged to three different groups: low, medium and high, based on their initial scores on the Personal Science Teaching Efficacy beliefs survey (as mentioned in Chapter 3 in detail). Six participants belonged to each of the three groups mentioned above. The selected participants’ pre-post PSTE scores (as explained in detail in Chapter 3) and the interviews conducted with each group participant provided a detailed picture on how self-efficacy beliefs changed after participating in the course. Figure 5 shows the average percentages (raw-mean scores) of self-efficacy raw scores of group participants for pre-PSTE and post-PSTE scale. An increase in PSTE percentage scores (based on raw-mean scores) was found from pre-test to post-test for all three groups: low group (pre raw-Mean= 33.67, 52% and post raw-Mean= 44.17, 68%), medium group (pre raw-Mean= 42.67, 66% and post raw-Mean= 54.5, 84%), high group (pre raw-Mean= 55.84, 86%, post raw-Mean= 58.17, 89%). For the high group, it is likely that the increase in the gains (based on raw mean pre and post-test PSTE scores) was influenced by the ceiling effect, inability to estimate or assess gains above a certain level (Leonard et al., 2011).
Qualitative findings

This section documents the qualitative picture of participants’ changes in science self-efficacy beliefs over time from participating in the course. Given the qualitative nature of the findings, the description of participants’ self-efficacy beliefs is supported by participants’ voices across the data. Two interviews, one at the beginning of the semester and the other towards the end of the semester were conducted with eighteen participants. The similarities and differences within and across groups (i.e., high group (N=6), medium group (N=6), and low group (N=6)), resulting from cross case analysis, are also discussed.

As interviews were the primary source of data, several excerpts directly from the interview transcripts are presented. The excerpts from the participants’ interviews are represented in a scheme to identify the group the participant belongs to, whether it is first or the second interview, and the semester when interview was conducted. For example, 1M-2-S indicated 1st participant in the medium group, 2nd interview conducted in Spring

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**Figure 5.** Pre- and post-PSTE average percentages of participants from all groups.
semester 2013. Similarly, 6H-1-F indicates 6th participant in the high group, first interview conducted in Fall semester 2013.

The interview responses supported the quantitative results that showed significant gains in participants’ self-efficacy beliefs. The qualitative evidence of the increases in self-efficacy beliefs were most prominently demonstrated through the ways in which elementary preservice teachers talked about themselves as future science teachers and their confidence to teach science. The participants’ perceptions of themselves as science teachers was defined as science teacher self-image. The section below will address the development of participants’ science teacher self-images and confidence supported by the interview data. This section will be followed by the discussion of challenges that detracted participants’ development of self-efficacy beliefs.

Science Teacher Self-image

**Initial picture at the beginning of the course.** In this section, the participants’ initial science teacher self-image is first discussed followed by the evidence supporting shifts in participants’ views of themselves as science teachers. At the beginning of the semester, all group participants were asked to provide responses on whether or not they see themselves as future science teachers. The group participants’ initial responses on their own self-image as science teachers varied across 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-S). Similarly, several other low group participants’ responses 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 13 for more examples from group participants’ first interview).

In contrast to these responses, which suggested a negative self-image of the low group participants, 5 out of 6 participants from the high group had a positive image of themselves as science teachers. Their responses indicated their strong desire to teach science and that “understanding science is important for their future kids” (5H-1-F). These participants often cited strong affinity towards science originating from their positive science experiences in prior science classes, which they stated as their motivation to become future science teachers. For instance, a participant from the high group stated, “I loved the material [refers to science] in my science classes and I would love teaching it and hopefully inspire people to like it as much as I like it because I like teaching science” (1H-1-S).

Another participant in the high group was the only exception to the trend whose response suggested her discomfort with science as an influence on her initial negative self-image, she said, “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-F). This participant was placed in the high group based on her high scores on the pre-PSTE scale; however, her responses during the first interview seemed to contradict with her quantitative scores. 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-F). The positive comments made by her seemed to contradict her negative self-image of a science teacher, which makes this participant worth mentioning.
Interestingly, only 2 out of 6 medium group participants expressed similar passion for being a future science teacher as the high group, the remaining 4 participants did not self-identify themselves as science teachers. The responses indicated a reoccurring reason for those medium group participants who did not identify themselves as science teachers – either science not being their main interest or they see themselves as an elementary teacher teaching all subjects and not specifically science. For instance, a participant from the medium group stated, “Not really [refers to future 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-F). Table 13 exhibits a series of excerpts that provide more examples from the high, medium and low group participants’ responses to their first interview and the second interview (where appropriate, critical words or phrases are italicized).

**Final picture towards the end of the course.** At the end of semester, all group participants were again asked to provide responses on how their view of themselves as future science teachers had changed after their participation in the course. Many group participants’ responses indicated positive shifts in their science teacher self-image from what they stated at their first interview conducted at the beginning of semester. 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-S). These participants from the low and medium group were further asked to elaborate on how their view of themselves as a science teacher changed, the majority of participants stated that the ways in which the content was presented in the
course provided them with the ideas for future teaching. Specifically, the participants seemed to be benefitted by the science experiences they had in the course that allowed them to witness fun ways to teach science. As a participant from the medium group 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-F).

Conversely, all of the high group participants’ responses, except the fourth participant, did not indicate any shifts in their science teacher self-image and maintained their positive self-image that they talked in their first interview. The fourth participant from the high group, 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.” Table 13 presents representative excerpts of group participants’ interview responses from the first and second interview. 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).

Table 13

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

<table>
<thead>
<tr>
<th>Group</th>
<th>Participant</th>
<th>First interview</th>
<th>Second interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>4L</td>
<td>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.</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td>5L</td>
<td>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</td>
<td>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</td>
</tr>
</tbody>
</table>

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The above excerpts suggest that participants’ positive science teacher image supported their personal science teaching efficacy beliefs – that they can teach science.

Another set of interview questions were specifically targeted in order to get a detailed understanding of group 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 ahead of their future students and the ways in which participants described their future teaching outcomes provided an understanding of their outcome expectancy beliefs.

The majority of high and medium group participants’ responses indicated that they are confident to be able to enhance student outcomes through their teaching. Most of them shared that they learned effective ways of science teaching from their own positive science experiences in the course, so they believed that their future elementary students would also learn from them. These participants further elaborated that they are willing to incorporate effective ways into their teaching from what they learned in the course such as hands-on experiments to make science interesting. The selected set of excerpts exhibit this tendency (relevant text is italicized):

3M-2-S: 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**.

1H-2-S: I think **how you teach it definitely effects how they learn it**. So I like to think that **hands-on and applying it in different way** that hopefully I will be able to **help them learn**. You try to teach them how to be interested in stuff, so I think it **have an effect not only on their grades in science but across the board**.

Another strong evidence of participants’ positive shifts in outcome expectancy were from the ways in which several participants from the high and medium group talked about the ways they will prepare themselves to ensure successful students’ outcomes. For instance, a participant from the high group said that she would “do additional research and figuring it out before I present to the class, that way I would be knowledgeable and be able to explain to them everything” (2H-2-S). She went on to explain how she would approach
teaching to ensure that all students learn, as she said: “If I can tell that they [future students] are not getting it, will figure out a different way to approach it or additional help to make sure that they understand.”

In contrast to the responses provided by the high and medium group participants, the low group participants’ responses indicated that not all participants from the low group had been able to move beyond their discomfort with science to actually believe that they would be able to make a difference in their students’ achievements in science. These participants often complained about their own content preparedness to be able to help their future students learn science from them. A participant from the low group said, “but I would like to know little bit more to be able to really help them know everything that they need to know for specific grade level” (4L-2-F). Similarly, another participant’s response reflected similar concerns and demonstrated low outcome expectancy, as she said, “I think that the teacher has so much influence on the students, just what I know right now…I don’t think I am prepared enough” (3L-2-S).

Enhanced Confidence for Teaching Science

In this section, the participants’ initial levels of confidence for teaching science is first discussed followed by the evidence supporting participants’ new levels of confidence. At the beginning of the semester, group participants were asked to rate their initial level confidence to teach science on a scale of 1 (very low confidence) to 5 (very high confidence). The initial level of confidence indicated by low group participants ranged from 1-2, medium group between 2 and 3, and high group ranged from 3-5. When asked to explain their choices, a majority of participants from the low and medium group indicated a lack of science teaching experience or lack of content preparedness as the two
major issues for low levels of confidence. A participant from low group discussed her concerns with science and lack of confidence in her ability to teach science: “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-S). Table 14 presents more excerpts from the high, medium and low group participants’ responses to their initial levels of confidence at the beginning of the semester (where appropriate, critical words or phrases are italicized).

During the second interview conducted towards the end of semester, a majority of group participants credited their science experiences in the course to help them gain new levels of confidence in their ability to teach science in future. When asked again to range their confidence level to teach science on a scale of 1 (very low confidence) to 5 (very high confidence), the low group participants’ range increased to 3-4, medium group participants chose 4 as their confidence level, and most of the high group participants maintained their high confidence indicating their choices of 4.5 or 5 as their confidence levels. These participants felt confident in the ways in which content was presented in the course that they believed provided ideas that would help their future students learn. 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-F). Table 14 presents more examples from low, medium and high group participants’ second interview responses, which demonstrates positive shifts in their confidence to teach science in the future (where appropriate, critical words or phrases are italicized).
<table>
<thead>
<tr>
<th>Group</th>
<th>Participant</th>
<th>First interview</th>
<th>Second interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>2L</td>
<td>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.</td>
<td>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. 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.</td>
</tr>
<tr>
<td></td>
<td>4L</td>
<td>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.</td>
<td>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. 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.</td>
</tr>
<tr>
<td>Medium</td>
<td>2M</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5M</td>
<td>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.</td>
<td>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.</td>
</tr>
<tr>
<td>High</td>
<td>4H</td>
<td>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</td>
<td>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</td>
</tr>
</tbody>
</table>
knowledge on how to get things through to kids. 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.

learned and turn into a lesson plan for the kids. 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.

In addition, several salient comments from high and medium group participants suggested that the positive shifts in confidence also played a role in shaping their outcome expectancy beliefs – ability to enhance future students’ learning in science. For example, a participant from the medium group said: “I am definitely a lot more confident in the basic concept of physics… I would be a very good science teacher just because I like to be hands-on with my students [refers to future students].” She went on to talk about her future students and said, “I would be able to answer any questions that they [future students] do have” (5M-2-F).

The expressions of positive shifts in their outcome expectancy were more evident in the high and medium group, the participants from the low group did not link their personal gains in confidence to teach to their future student gains. For example, a participant in the low group expressed confidence in her own learning: “I only understand it to a certain extent for me to understand it”, but she expressed negative outcome expectancy regarding her future teaching as she continued, “But I don’t know if I can help someone else to totally understand it as well” (1L-2-S).

In summary, trends showed positive changes in most of the group participants’ science teacher image and confidence after participation in the course. Only a few participants from the low group indicated self-doubt about their image as a science
teacher emerging from the perceived lack of confidence in their science content preparedness as a whole. Furthermore, the lack of content knowledge and low confidence seemed to interfere with some of the low group participants’ outcome expectancy beliefs and that they seemed to be less comfortable to be able to influence student learning through their future science teaching. The next section discusses some of the persistent challenges in detail, as described by the group participants.

**Persistent Challenges**

It is clear that the course experiences resulted in, for the most part, positive shifts in the self-efficacy beliefs of participants across all groups. However, when asked, most participants volunteered information related to persistent concerns. Four major challenges stated by group participants were: transforming content for an elementary classroom, self-doubt on the content-preparedness, long-term impact of the course, and handling the complexities involved with classroom teaching. The representative excerpts for each challenge is listed in tables below.

**Transforming content for an elementary classroom.** The major challenge revealed from participants’ comments was uncertainty about how to transform the content learned in the course into lessons relevant for elementary learners (see Table 15 for representative excerpts where appropriate words or phrases are italicized). Even though a majority of group participants realized that the course was not directly focused on how to teach, they expressed the need for being able to discuss more about what the activities would look like in an elementary classroom. Although the course offered many examples of how activities will help elementary students get interested in the science
topics, participants expressed concerns about whether the activities they performed in the course along with the pace of the content would be a good fit for an elementary learner.

Few participants mentioned the lack of opportunity in the course for them to be able to plan and create at least one elementary science lesson on their own based on the topics learned in the course and to be able to teach it to their fellow-mates. A lack of first-hand science teaching opportunities in the course led the majority of low group participants to question the direct applicability of the science lessons learned in the course into an elementary classroom.

Table 15

*Transforming content for an elementary class as a challenge posed by participants*

<table>
<thead>
<tr>
<th>Transforming content for an elementary classroom</th>
<th>Representative Excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low group</td>
<td><em>I wish that there were more opportunities...more often we talk about specifically an elementary student...like you may run into this issue</em> in your classroom when your student asks this kind of question. I know that that’s something that I would run into in my next...how to teach elementary science course but that would have been cool specifically for physics because the stuff we learned getting like a circuit to light a light bulb then <em>how could an elementary student do the same thing.</em> (3L-2-S)</td>
</tr>
<tr>
<td>Medium group</td>
<td>It would have been nice to <em>may be design a lesson of our own and see and teach it to our peers.</em> There were a lot of times when people did not understand things and I felt that I can may be explain it to them and may be that would have benefitted me. (2M-2-S)</td>
</tr>
<tr>
<td>High group</td>
<td>I feel like a lot of this class...I guess it is just more...<em>I feel like it would all go over elementary kids's head, they are not going to need to know this</em> or they are not ready to learn this. Probably sometimes with elementary kids they do not need to know all the stuff that we have learned so <em>the hard part of me is to...I do not want to say dumb it down but get it back down to an elementary level.</em> (4H-2-F)</td>
</tr>
</tbody>
</table>

**Self-doubt on the content preparedness.** One of the most consistent concerns expressed by the participants from the low and medium group were self-doubt on their
content preparedness – whether their content knowledge is enough to be able to explain science concepts to their future students. The fear of encountering unanticipated questions from future students, unsure of providing satisfactory responses to student questions, and whether they could provide in-depth explanations on science topics were of continuing concerns to the low and medium group participants. Conversely, responses from the high group participants frequently indicated high content understandings and high confidence to be able to teach science in the future (see Table 16 for representative excerpts where appropriate words or phrases are italicized).

The low group participants also talked about their concerns with the amount of time spent on investigating some of the science topics, which they believed was less than what they had expected. These participants further mentioned that they felt rushed through certain topics taught in the course such as force and motion, which was covered towards the end of the semester. They expressed the desire to be able to explore forces and its effects in a greater depth to be able to develop sufficient understandings rather than rushing towards the end due to time constraints.

Table 16

Self-doubt on content preparedness as a challenge posed by participants

<table>
<thead>
<tr>
<th>Self-doubt on content preparedness</th>
<th>Representative Excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low group</td>
<td>Because <em>I do not want to teach anything that I do not know I am doing correctly</em> or a having a background where I could feel confident teaching someone else or the entire classroom. <em>I do not like to have to act like I know more than I really do</em> ever as much as I do not know it and then be able to teach it having like a second guess. (5L-2-F) I feel like it really did help prepare me a lot for physics but I feel like some of the concepts…<em>maybe we could have gone more in depth or spend longer time</em> learning them. I feel like the content that we learned was very straight forward but <em>we did not go very deep</em> into a lot of the concepts. (4L-2-F)</td>
</tr>
</tbody>
</table>
I would say because I definitely know a lot more physics than I did before, but there are still some things that I may be want to learn. I want to explore stuff like…which I guess is more in depth in force and motion. (2L-2-S)

Medium group

I think well I am going to teach elementary...I think there is just going to be so many questions. Some student might just ask me a question that I just have no idea about. They might think of just random questions that I really just won't know the answers to it…that I don't have the knowledge for…I don't want them to think that I am not credible in science. (3M-2-S)

Complexities involved with classroom teaching. The participants from all three groups repeatedly said that the course did not prepare them for the unanticipated situations that could arise in their future classrooms (see Table 17 for representative excerpts where appropriate words or phrases are italicized). Some of the complexities involved with classroom teaching described by the participants included: handling students’ behavioral issues, failure of activities to go as planned, failure of technology, unanticipated experimental results, lack of supplies or resources to conduct activities, and how to address diverse students’ needs. The group participants’ responses clearly indicated their hesitation to confront with some of the complexities involved with future classroom teaching. The participants said that they wanted to discuss more examples and specific issues involved in elementary teaching, discussion on how certain activities could pose more challenges for certain elementary students, and strategies to prevent chaos if encountering unanticipated results from experiments or if an activity failed during the class session.
Table 17

Complexities involved with classroom as a challenge posed by participants

<table>
<thead>
<tr>
<th>Complexities involved with classroom</th>
<th>Representative Excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low group</td>
<td>I guess if there is just like one teacher and so many students...how can that be. How can we prevent chaos from happening in that...I wish that there were more opportunities...more often we talk about specifically an elementary student...like you may run into this issue in your classroom. (3L-2-S)</td>
</tr>
<tr>
<td>Medium group</td>
<td>I don't think in all elementary schools will have as much supplies or as many supplies that physics building probably has right here so that we can just go back and find a different activity so I feel like it was almost unrealistic how much stuff that you guys had in the back to do experiments with and so I think it did not prepare us in a way that we would not have all the supplies so it would be harder to make as many activities I guess...was not really realistic. (1M-2-S)</td>
</tr>
<tr>
<td>High group</td>
<td>There are challenges that you can face, may be some of the technology may not work, you may not have all the material so you have to improvise and make the best of all the situation. (4H-2-F)</td>
</tr>
</tbody>
</table>

**Long-term impact of the course.** Some participants from the low and medium groups were concerned about the long-term impact of the course. This pattern was not observed in the high group comments, rather the participants talked about retaining the content knowledge for a longer period of time. The comments from the low and medium group participants implied that they had concerns with knowledge-retention – whether they would be able to retain all the content and specific activities learned in the course by the time they are in their future classrooms. A participant from the low group stated in her second interview: “I feel like I might forget the little stuff [refers to content]. I still do not know if it would come as super natural so I do not know if I would be the best at it [science teaching]” (6L-2-F). Another participant from the medium group raised similar concerns about the time-lag between the content course and the time she will be a classroom teacher. She said: “If I had space in between this class and teaching then I probably would not be as effective.” Her major concern was that unless the ideas learned
in the course are reinforced again, she is more likely to forget examples, specific activities, and meaningful discussions on how things worked and that might decrease her efficacy to teach. As she said, “I do not think I would remember exactly what did not happen or…what was the best example to explain it and that would make teaching more difficult. I think knowledge needs to be reinforced” (1M-2-S).

In summary, it is possible that the challenges mentioned may have an influence on participants’ self-efficacy beliefs to some extent, but as a whole, evidence suggests that the group participants showed positive shifts in their science teaching self-image (i.e., self-view of oneself as a science teacher), confidence to teach science topics learned in the course, and significant gains in content understandings (evident in quantitative gains and qualitative quotes). The lack of practice teaching experience and the inadequate understanding of aspects involved with how to teach in a classroom seemed to influence participants’ outcome expectancy. The notion is also supported by the quantitative results where the effect size analysis showed that the personal science teaching efficacy (PSTE) had a larger effect on the change from pre to post-testing of self-efficacy than outcome expectancy (STOE) that showed a moderate effect.

**Question 1b**

What factors associated with the specialized physics content course contribute to changes in preservice elementary teachers’ science self-efficacy (PSTE and STOE) beliefs?

The research question 1b aimed to identify the factors associated with the specialized physics content course that contributed to participants’ improved science self-efficacy beliefs. The interviews served as the primary source of data and secondary
sources included observations and artifacts. The first interview questions were designed to identify the factors that influenced participants’ prior self-efficacy beliefs at the beginning of the course, for instance: Describe your experiences from the science classes prior to entering college? The second interview questions were designed to identify the course factors that contributed to participants’ enhanced self-efficacy beliefs. The group participants were asked, for example: Describe specific incidents that happened within the course that influenced your confidence to teach science? The participants’ descriptions of course-related factors were categorized. The categories that emerged from the cross-case analysis of participants’ interview data were contributing factors for changes in participants’ self-efficacy beliefs. These categories are described in detail below.

**Contributors to Science Self-efficacy Beliefs**

The analysis of the data resulted in four major categories that are contributors to improvements in participants’ science self-efficacy beliefs after their exposure to the science content course. These categories are: enhanced science conceptual understandings, active learning experiences, teaching models, and instructor role model. Some categories have sub-codes within the category. Figure 6 displays the list of categories along with sub-codes across different groups. The categories are described in greater depth below.
### Figure 6. Categories and its connections to the self-efficacy beliefs across groups

**Enhanced Science Conceptual Understandings and Increased Confidence**

A majority of the participants from all three groups 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 said:

> 4L-2-F: 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.

Time spent on science activities and grade-appropriateness of the content were two important factors. The participants mentioned that they felt more prepared to teach
science content because of the pace at which learning progressed and the content taught was relevant for future elementary teaching. For instance, one participant shared, “It’s [refers to the content course] definitely worked on the basics, which is being in elementary- wanting to teach elementary school so it definitely mean more confident in that” (1H-2-S). Another participant said, “I felt like this class took time with everything, I think that was really helpful so you could understand it at a better level which would make sense for people or teachers” (5L-2-F).

During their first interview many participants had expressed concerns on their lack of content knowledge and now they felt confident that they could teach science. 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-S). Furthermore, participants’ comments also indicated that enhanced science understandings improved their ability to address students’ questions in the future. As one participant said, “Course made me understand it in more depth…Like if a kid would ask me a question I would know how to answer it” (6L-2-F).

Enhanced Science Conceptual Understandings and Positive Shifts in Attitudes

Participants’ responses indicated changes in their attitudes towards science and science teaching, which were demonstrated from the ways in which they talked positively about science and science teaching. The majority of group participants explicitly stated that the ways in which science content was taught helped them realize the relevance of science in their lives and thus, they felt more connected to science. For instance, one participant shared how learning about forces in everyday life helped her see science
differently than before. She expressed that she is more likely to include science topics
taught in the course in her future teaching. She said:

2L-2-S: *Before I did not know forces and motion* and what types there were like
normal forces and gravity and *so now I know there is always force of gravity on us.* I guess *I feel like beliefs have changed...like science is a big part of teaching and like it's in lot more things than I thought before.* I think *I like science more now* because I know more about it.

At the beginning of the course, many participants stated being scared of physics
but now felt positive about physics, as one participant said, “I feel like I have opened my
mind more than before. Being able to think about physics definitely opened my mind.
Yes, it’s not the worst subject of the world anymore” (1M-2-S). Not only the participants’
attitudes towards physics changed, their comments indicated that now they are more
willing to teach physics in the future. As one participant stated:

(2H-2-S): I always heard that it was kind of hard, so *I kind of had negative feeling
towards physics* because I never had physics class before. So *I know all this stuff
that I did not know before.* So I think *it would help me in the classroom in the
physics part* like with the circuits and stuff with the kids.

The participants were further asked to elaborate on their personal experiences in the
course that they think benefitted them to be able to teach science in the future. The next
section describes some of the course experiences as stated by the group participants.

**Active Learning Experiences Increased Confidence and Provided Potential Ideas**

The participants from all three groups talked about the benefits of the active
learning strategies that the course offered. They felt that the science learning experiences
enhanced their confidence to teach science and provided them with potential ideas to rely
on for their future science teaching. Participants’ descriptions included hands-on
activities and working in small groups that they felt beneficial for their own learning as
well as for their future teaching.
For many low and medium group participants, this course was their first time exposure to the hands-on activities and conducting science investigations. The low and medium group participants particularly appreciated the hands-on experiences that allowed them to take charge of their own learning. This experience helped them to develop as independent thinkers, which was different than what participants had experienced in their prior science classes, and introduced them to more effective ways of teaching science. They further explained that the problem solving element of the course afforded them potential ideas to teach science effectively in their future classrooms.

When asked to elaborate on ideas for future teaching, one participant from the low group referred to elementary students and emphasized the fact that “the hands-on activities are going to make elementary students excited about science and about learning” (3L-2-S). These participants felt that they were more interested in learning science through hands-on activities, so now they could use similar activities to help their future students learn science. Another participant from the medium group mentioned that the ways in which the course content was taught made her feel confident about her own future teaching. As she said, “how bulb lights and being able to be hands-on, now I feel like I would be a very good science teacher just because I like to be hands-on with my students and make sure they are understanding it” (5M-2-F). She further mentioned that working with materials first-hand allowed her to see how a light bulb works so she is positive that the activities will be fun and exciting for younger kids as well.

Similarly, the participants who initially thought of avoiding teaching science mentioned that their perceptions of science teaching had changed and that they are more likely to teach science in the future. They felt that they are better equipped with the ideas
for conducting science explorations with their students in the future. Having more ideas to teach increased participants’ self-confidence and several of them said that they could see themselves teaching science in the future. Two participants described their experiences with hands-on learning that influenced their views on future science teaching:

6M-2-F: It was more hands-on and not like a regular lecture class. I think just the way the class was set up got me more interested in science in general because I was more eager to learn. I think you are more confident to teach it the way you are prepared to set it up. I think just the class as a whole made me more like teach it more, just the different ways you can teach it like with experiments, get your students involved.

1L-2-S: Before, I don't remember doing so much hands-on activities, so I would just say...all those activities that we did in class, the explorations...kind of like changed my idea that now I can teach...because it gives you more ways of looking at things. She [refers to instructor] was kind of showing us ways that we could do hands-on activities with our class as well, so that was helpful to see how that can be used in your classroom too.

Participants from all three groups also mentioned about the real-world examples used in the course and that elementary students will also be motivated to learn science through the real-world examples used in the class, for instance, how gravity acts on us or the forces that act on us when we sitting in a bus. Participants talked about the instructor using examples that are fun such as M&Ms to illustrate electron models showing how electrons move inside a circuit and that they think will help elementary students to understand abstract phenomena of the current flow in a circuit. As one participant said:

4L-2-F: I really liked when we did the electron models and she was showing us how electrons move in order to get over something, you have to give away one and she used M&Ms. That was really simple but it was memorable, because everyone likes M&Ms and stuff you are paired up back together and you are like oh well that is what it means because that is what we are doing like we are walking in the circle and then you have to pass or you have to give away one.
The group participants also seemed to benefit from the PhET simulations and saw those as useful examples for teaching with technology. They elaborated that the experiences gained while conducting PhET simulations that had batteries and bulbs showed them concrete examples to help future elementary students build their own science understandings. One participant mentioned that the PhET explorations were set up for ‘failures’ for them to be able to see what works and what does not, which they could conduct in an elementary classroom to help students figure out on their own. As she said:

1M-2-S: *She had us almost set up for failures in some of the experiences* or experiments just so we could see what works and does not work and I think that was pretty cool. And also *on the computer with the PhET simulations were it would light the battery and fire...I think in an elementary school the kids would think that was really cool but then they would also know it’s dangerous so they can figure out what’s right and what’s wrong easily.*

In addition to hands-on learning, participants from all three groups were positively influenced by working in small groups, and they saw the collaborative learning as an effective strategy for their own future classrooms. A majority of participants reported that they felt comfortable sharing ideas in small groups, critiquing (and being critiqued by) peers they could trust, and presenting their evidence-based findings to the larger group. They mentioned that explaining concepts to their peers was a good practice for their future teaching and felt confident that they can teach the same concepts to their future students. As one participant said:

5M-2-F: I think that *being able to be involved with my peer groups* as well or my peers in my lab groups in the course, I think *being able to explain it to them* how I am comprehending and them being able to explain it to me...I think that it is *helping me in understanding how to teach it as well.*
Some participants further mentioned that working in collaboration had two benefits for their future classroom — the students who have higher understandings can help the kids who are struggling and at the same time collaboration also helps kids at higher levels to practice what they learned while helping their peers understand. As one participant said:

5H-1-F: There is going to be some kids who are above the rest of the class which is exactly what happened in this course and there is going to be some kids who do not get it and you have to...I think that is why the group work is important because it kind of bounces out and the kids who are very very smart can keep practicing and help the kids who are at a lower level.

Participants often mentioned white-boarding and poster-presentations as part of their small group collaborations that they see as useful techniques for their future classrooms. One participant explicitly referred to her future teaching as she said, “I feel like I could have stronger class due to the white-board like us” (1M-2-S). When asked to elaborate on how she felt white-board was helpful for her and her future teaching, she described:

(1M-2-S): Being a teacher I have always thought that it is hard to pick out the students that don't understand the subject because they are usually the shy ones that don't raise their hands so I feel like the white-board really helped the students to put down their ideas and them be fixed.

During the lessons, preservice teachers had a few opportunities to create posters in small groups and then present to the class. For instance, in one task students were asked to make posters showing examples from daily life to represent models of circuit flow. Some students saw these poster-making opportunities as a means for their future students to develop creativity in science. As one participant said, “I did like how we made the posters. I think that’s good that they [future students] could get their creative sense in science” (3M-2-S).
While many of the low and medium group participants were impacted by the new experiences they had with science investigations firsthand, high group participants appreciated hands-on experiments in this course as something that they have always enjoyed in their prior science classes. The high group participants mentioned that seeing another successful example of science teaching through this course reinforced their ideas on hands-on learning as an effective way to teach science. As one high group participant mentioned, “I am definitely going to be very hands-on, which I always felt like I was before. But after this class I really really feel like, that I am going to like be very hands-on and have the kids do their own experiments to figure things out” (2H-2-S).

Furthermore, most of the high group participants seemed to be convinced that hands-on experiences would help them retain their content knowledge for a longer period of time, so they could rely on their experiences to be able to teach it effectively in the future as well. As one participant said, “Having all the hands-on activities I feel like I will keep this knowledge for a longer because I have the experiences that I can tie it back to…to hope that other students would also be helped” (2H-2-S). She further elaborated that she “got some good examples on how to teach it to other kids just through the experiments and exploration” (2H-2-S).

**Teaching Strategies as Exemplars for Future Science Teaching**

In addition to the active learning experiences, participants’ also described teaching strategies that showed them examples of successful pedagogical models for future teaching. The teaching strategies that participants indicated that they benefited from were – the learning cycle and multiple representations of the content. Several participants indicated that the class was set up like a ‘modeled classroom’ in the same
way that they would teach future elementary students. For instance, as one participant said, “the way she runs the classroom is also...she kind of runs like a model like how we would run a classroom” (4M-2-F).

**Learning cycle approach.** Learning cycle approach was a teaching model that the participants talked about as a useful tool for science instruction. More participants from the low and high group made statements about their positive experiences with the ‘learning cycle’ approach used by the instructor to teach each science lesson. Such positive experiences with learning cycle helped participants to see effective ways to teach science. As one participant said, “I really liked how she does learning cycles everyday…like how there is a question and then we talk about it. I really think that is an effective way to teach” (4H-2-F).

Some participants from the low group mentioned their first time exposure to the learning cycle. These participants, who had not experienced learning cycle before, seemed to see more benefits of teaching through the learning cycle as opposed to the traditional approach. As one participant said, “I thought that was an interesting thing that we did not necessarily go by the book but we went by the learning cycle, so the way that it was taught helped me think like as if you as a teacher want to get students excited” (6L-2-F). The participants were further asked to elaborate on how the learning cycle approach changed their views about science teaching. Several participants from the low and high group commented that the ways in which learning cycle progressed showed them ways how science teaching should look like. Participants mentioned that they liked the step-by-step investigation that the learning cycle offered towards building their understanding of
the science concepts and said that now they are more willing to teach science through this approach. As one participant mentioned:

4L-2-F: *The learning cycles I really did liked it* because it was like the main cycle learning so it would be like what is current and it would be broken down but *inside the main cycle there would be four more questions then made it always relate back to the main question and it tied everything together* because I feel like I kind of know I like things connected together so in this class when we had it like that, it really showed me that I really did learn that way a lot better. *Personally I learn that way a lot better so I would want to try and teach that way too.*

Several other participants echoed that the learning cycle provided clarity to *why* they are learning *what* they are learning, so they believed that their future students would also be able to learn by the ‘learning cycle’ approach.

**Multiple representations of the content.** Participants from all three groups tended to make statements that the content was presented to them in multiple ways, which assisted them to see different ways to teach diverse learners. For most of the low-group participants, this was their first experience where they were exposed to a variety of ways to approach teaching science in their future elementary classroom. As one participant said that the “course showed me that as a teacher you can change your way of teaching for elementary students, so thought that was something that was different.” (2L-2-S). She further described that the combination of hands-on experiments and instructor providing relevant information through short lectures helped her learn and now she is more willing to adapt her instruction according to her students’ needs. As she said:

(2L-2-S): *It [course] showed me that there are different ways to teach the topic I mean I guess I will switch and do that because whatever works best for my students…that is what I will do. Different ways would be that she would have sometime little lectures about basic information but it would only be after we could not try to construct on our own ideas about, example when we first started playing with circuits and stuff, we had our ideas in our head and then she would give the lecture over, like a little lecture over the stuff which I thought helped because it showed you that…like reaffirm your ideas and made it concrete.*
Furthermore, the participants also stated that they saw the instructor using multiple representations of the content to make adjustments to the lesson according to students’ needs. The instructor incorporated different ways and examples to explain the same concept to individual students, which they recognized as a challenge for any classroom teacher. Such experiences of witnessing their instructor addressing the needs of all students in the content course with different learning styles, the participants from all three groups stated that they were more likely to use different representations while teaching science in the future. As one participant from medium group mentioned:

(1M-2-S): I think we challenged her [instructor]…as a bunch of different students learn different ways and so she had to come back the next class and give alternate examples to explain those who learn differently so I feel like I have…that’s the big challenge in teaching that not all students learn the same and so I think she did a good job of showing us multiple ways to explain the same thing.

Several other participants from all three groups mentioned that they liked multiple representations of the content, which they described as the ways the instructor used to address diverse learners such as: conducting hands-on experiments (kinesthetic and visual learners), delivering short lectures (oral) that summarized key points of the lesson, writing important information on the white-board or smart-board (visual) for students to take notes in their science journals. Furthermore, participants talked about a variety of alternative examples that the instructor used such as: drawing diagrams on the large white-board, showing science demonstrations such as electroscope to explain static electricity, or a science video for students to see and hear. These experiences of instructor modeling multiple representations afforded participants with successful ways to meet all students’ learning needs in their future classrooms. As one participant mentioned:
It prepared me to be able to adjust and try different methods to teach. Some kids are better at looking at the board and taking notes down which we did in class. Some kids have to have hands-on experiments, they learn through doing hands-on activities and experiments or just to keep them engaged so that they would not fall asleep in class so I think whatever the students’ needs are you are to be able to meet them in whatever way is best for them.

In addition to being exposed to the teaching models that benefitted participants from all three groups, the instructor stood out as an ideal science teacher as discussed in the next section.

**Instructor as a role-model**

The course instructor’s teaching approach was successful in changing the preservice teachers’ views about science teaching, as the instructor appeared to be a positive role model to all participants. Participants’ described three specific attributes of the instructor: instructor’s enthusiasm for science teaching, questioning strategy and explanations, and genuine interest in student learning. Participants’ responses revealed that the course instructor was approachable, enthusiastic, showed genuine interest in their learning, and challenged students’ thinking through open-ended questions. As a result, many students saw their instructor as an ideal science teacher. As one participant said, “she was a good influence because that’s what makes a good teacher being there for your students and answering questions so, I hope I could be like that too” (1L-2-S).

**Instructor’s enthusiasm for science teaching.** The course instructor’s enthusiasm for science and science teaching made a positive influence on participants and made them realize how a teacher could influence students’ motivation to learn science. The participants’ responses suggested that the teacher was very involved with the material and that clearly communicated her excitement about science to the preservice teachers. Several participants realized that the instructor’s energy could get them excited
about the topic, so now they could influence their future students to learn science as well. As one participant shared:

1M-2-S: *She was very excited about the subject and I was not originally* but her getting excited about the little less things kind of made me and my group more interested because we wanted to know why it was so exciting. *If I go in [refers to future classroom] with just as much excitement as her…as its hard to get excited about it but now I know the right way to teach it. I think any subject students will be more interested if teacher is more interested.*

In particular, the low group participants were greatly impacted by the instructor. For many of them, it was their first experience with a science teacher who was enthusiastic as compared to their high school science teachers, as one participant shared, “She was very involved and I think that is a very good example of someone who take teaching very seriously” (5L-2-F). For these participants, the instructor was a great positive influence of how a science teacher should be.

**Questioning strategy and explanations.** Several participants from all three groups reported that their beliefs about science teaching changed by seeing the instructor’s openness to ask questions. They felt that the instructor created an environment that they were not afraid to ask any questions they had unlike other science classes. Such demonstrations of modeled teacher behaviors created a positive impact on participants and provided ideas to run their own classroom. As one participant said, “The instructor is very good at listening to my weird unorganized questions and coming up with an answer. Seeing a teacher have this knowledge who could answer my questions and provide solid examples…that helped” (2M-2-S). Participants realized that creating an environment similar to what they had in the course where the students are welcomed to ask questions would benefit their future students the most.
Another strategy that the participants appreciated was that the instructor circulated around the room and asked questions to help students explain their findings. They particularly liked the instructor coming to their tables and urging them to explain what they found because it provided encouragement and support to them. The participants also pointed out that the teacher attended to individual questions while circulating in the classroom, which helped some shy students who did not want to speak aloud. Seeing all the actions that the instructor performed made participants realize that they could also help the shy students to learn science. As one high group participant mentioned, “I felt like it was good that she came up to all of us individually, because some people don't like to ask questions in a big group. So doing that in the classroom I think would help some students learn better” (2H-2-S).

**Genuine interest in student learning.** The instructor’s willingness to help and be involved with all table-groups had a positive impact on all group participants, especially on the low group participants who had relatively poor prior experiences with their prior science teachers. The participants indicated that the instructor had genuine interest in every student’s understanding of the phenomena being explored and thus, they felt that the instructor cared for them. As one participant from low group mentioned:

6L-2-F: *She really did good job in making sure that we understood it before she moved on, which on any subject it build on itself so I mean it helps to understand one thing before moving on to the next thing. I think the way that she taught, you can tell that she cared about.*

The instructor treated all students as if they are teachers already and thus, every students’ opinion and ideas were respected. As one participant said, “she did not talk on to us and treat us like I mean we are her students. She talked to us like we are teachers
already” (3H-2-S). Seeing the ways the instructor made efforts to help every student learn science helped participants to realize how a successful science teacher should be.

In summary, the content-rich science learning experiences along with the modeled teaching strategies contributed positively towards students’ understanding of the science content and confidence to teach science. The hands-on learning, science models along with pedagogical modeling of teaching strategies, and teacher modeled behaviors provided potential ideas for participants to approach science teaching in their future classrooms.

**Research Question 2 and Sub-Questions**

**Question 2**

What is the relationship between preservice elementary teachers’ science self-efficacy beliefs and science conceptual understanding?

**Question 2a**

What is the relationship between preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) and conceptual understanding of physics prior to participation in the specialized physics course?

**Question 2b**

What is the relationship between preservice elementary teachers’ science self-efficacy beliefs (PSTE and STOE) and conceptual understandings of physics after their participation in the specialized physics content course?

**Question 2c**

What is the relationship between changes in science self-efficacy beliefs (PSTE and STOE) and changes in conceptual understandings of physics?
Findings of Research Question 2 and sub-parts

Research question 2 explored the nature of the relationship between elementary preservice teachers’ science self-efficacy beliefs and their science conceptual understanding before and after their participation in the specialized physics content course. Correlational analyses were conducted to investigate the nature of relationships between science self-efficacy beliefs and science conceptual understandings of preservice teachers.

Pearson Product-Moment Correlation

Pearson product-moment correlation coefficient ($r$) was calculated to obtain the correlation between two data sets. Results of the Pearson product-moment correlation analyses revealed no statistically significant correlation between pre-PSTE and pre-Content and between pre-STOE and pre-Content scores (see Table 18). Similarly, no statistically significant correlation was found between post-PSTE and post-Content and between post-STOE and post-Content scores. Further analyses revealed statistically significant correlations between gain in PSTE scores and gain in conceptual understanding; however, no significant correlation was found between gain in STOE scores and gain in conceptual understanding (see Table 18 below).

Table 18

<table>
<thead>
<tr>
<th></th>
<th>Content</th>
<th>Pre</th>
<th>Post</th>
<th>Gain</th>
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<td>.183</td>
<td>.349</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.217</td>
<td>.199</td>
<td>.012*</td>
</tr>
<tr>
<td>STOE</td>
<td>Pearson Correlation</td>
<td>-.124</td>
<td>.190</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.386</td>
<td>.181</td>
<td>.994</td>
</tr>
</tbody>
</table>

Note. *Correlation is significant at 0.05 level (two tailed)
Partial Correlation

Partial correlation coefficient calculation aimed at finding correlation between science self-efficacy scores on both scales (PSTE and STOE) and science concept test scores while controlling the effect of time. With time as a control variable, there was no significant correlation between PSTE and conceptual understanding and between STOE and conceptual understanding scores (at 95% confidence interval). However, correlation between PSTE and conceptual understanding was found significant at 90% confidence interval, STOE does not correlate with conceptual understanding (refer to Table 19).

Table 19

Partial correlations controlling for time (N=102, df =99)

<table>
<thead>
<tr>
<th>Control Variables: Time</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSTE</td>
<td>Correlation</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
</tr>
<tr>
<td>STOE</td>
<td>Correlation</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
</tr>
</tbody>
</table>

*Note. No significant results at 0.05 level, *Correlation is significant at 0.1 level (two tailed)

Summary of Findings

As presented in the sections above, the quantitative and qualitative findings suggested positive changes in participants’ science self-efficacy beliefs after their exposure to the content course. The qualitative analysis suggested positive changes in participants’ views of themselves as science teachers and confidence to teach science. Furthermore, the data analysis revealed four categories that served as contributors to science self-efficacy beliefs. They were identified as: enhanced science conceptual understandings, active learning experiences, teaching strategies, and instructor role-model. Some of these categories had additional sub-categories and were all addressed in
this section. In general, the content-rich science learning experiences along with the modeled teaching strategies contributed significantly towards preservice teachers’ science content understandings and boosted their overall confidence to teach science.

The study was also designed to understand the nature of relationship between participants’ science self-efficacy beliefs and science conceptual understandings before and after their participation in the specialized physics content course. No significant correlations were observed between pre- or post- science self-efficacy scores (both scales) and pre- or post- science conceptual understanding. Statistically significant correlations (including partial correlations) were found between the gains in PSTE scores and gains in science conceptual understandings; however, no significant correlations were found between the gains in STOE scores and gains in science conceptual understandings.
CHAPTER 5
DISCUSSION

This chapter is divided into three major sections. The first section provides a review of the purpose of the study. This is followed by the second section including detailed discussion of the findings and limitations to this study. The third section discusses implications of the study, possible future directions of research and concluding remarks.

Review of Purpose of Study

One of the major foci of science education reforms is to prepare high quality elementary science teachers. There has been growing emphasis on making comprehensive amendments in elementary science teacher preparation that are well-aligned with the demands of teaching high-quality science content outlined in the Next Generation of Science Standards as well as guidelines from other policy-making agencies (AAAS, 1993; NRC, 1996; NRC, 2012, NGSS Lead States, 2013). While much of the conversations about elementary science teacher preparation had focused on the issue regarding elementary teachers’ lack of content preparedness (Appleton, 2006, Hechter, 2011; Tosun, 2000), close attention was also paid on preservice teachers’ self-efficacy beliefs (Palmer, 2006b, Cantrell et al., 2003; Leonard et al., 2011; Yilmaz-Tuzun, 2008), which when developed during their teacher preparation programs are carried to their future classrooms (Bautista, 2011; Gunning & Mensah, 2011). Previous empirical work has consistently shown that teacher self-efficacy is linked to teachers’ classroom practices (Bandura, 1997; Tschannen-Moran et al., 1998), teacher behavior (Dembo & Gibson, 1985), preservice teachers’ attitudes (Mulholand & Wallace, 1996), motivation
and self-confidence (Bandura, 1986; Appleton, 2006; Rice & Roychoudhury, 2003), student learning outcomes (Bandura, 1977; 1982; Tschannen-Moran, Hoy, & Hoy, 1998), and student achievement (Tosun, 2000). Numerous studies have also shown that inquiry-based experiences in science methods courses enhance preservice teachers’ self-efficacy beliefs (Avery & Meyer, 2012; Brand & Wilkins, 2007; Gunning & Mensah, 2011; Rice & Roychoudhury, 2003); however, little is known about how preservice teachers’ science self-efficacy beliefs are developed in science content courses. A few studies put forth the notion that science content knowledge is a determining factor for self-efficacy (Bleicher & Lindgren, 2005; Hechter, 2011; Jarrett, 1999), but the empirical evidence to support these claims is limited.

The study was guided by two overarching research questions: (1) How do preservice elementary teachers’ science self-efficacy beliefs change during a specialized physics content course, and what factors associated with the course contribute to the changes in science self-efficacy beliefs? (2) What is the relationship between preservice elementary teachers’ science self-efficacy beliefs and science conceptual understanding? The discussion of the research findings are presented in the next section. This discussion is organized around important themes that emerged out of this study.

This study contributes to the body of literature focusing on preservice teachers’ self-efficacy beliefs in several ways. Foremost, it is one of the few studies exploring preservice teachers’ science self-efficacy beliefs conducted in the context of science content courses. Other studies focused on examining the effectiveness of science content courses without rigorous investigation of changes in self-efficacy beliefs (Doster et al., 1997; Duran et al., 2004; McLoughlin & Dana, 1999). More so, the methodology used by
these studies are restricted to using either a qualitative or quantitative approach. However, this study builds on the stance that using a mixed-methods design may provide a more comprehensive picture of the complex phenomenon such as self-efficacy beliefs. This study is therefore unique in identifying not only the changes in participants’ science self-efficacy beliefs through quantitative measures but also utilized student voices to understand the factors that influenced such changes.

Second, it is one of the few studies to examine the relationship between preservice elementary teachers’ science self-efficacy beliefs and science conceptual understandings within the context of a specialized science content course. This study attempted to explore the relationship in light of continuing debates in the field regarding whether or not science content knowledge plays a necessary role in improving preservice elementary science teachers’ confidence to teach science. Researchers working in the field have construed the relationship between science content knowledge and science self-efficacy beliefs in ways that are often conflicting. For instance, while some research studies propose that increases in science content knowledge could contribute towards increases in science self-efficacy beliefs (Bleicher & Lindgren, 2005; Hechter, 2011), others argue that it may not always be the case (Morrell & Carroll, 2003; Tosun, 2000). The intent of this study is to provide empirical evidence to address some of these contentions. More so, a majority of aforementioned studies have defined science content knowledge in terms of the number of science content courses and examined their impact on preservice teachers’ self-efficacy (Hechter, 2011; Swackhamer, 2009; Yilmaz-Tuzun, 2007). Other studies disagree with the notion that the number of science courses is a reliable measure for the science content knowledge (Morrell & Carroll, 2003; Tosun, 2000).
Thus, it is important to note that attempts to understand the relationship between science self-efficacy beliefs and science conceptual understandings are limited. This study attempted to not only test the relationship between science self-efficacy beliefs and science conceptual understandings but to pay close attention to understand the underlying processes involved in building preservice elementary teachers’ confidence in science as well as future science teaching through participants’ voices.

Third, 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 the science content course. No other studies focusing on preservice elementary science teachers, to date, conducted in the context of preservice elementary science content course have adopted this focus. In this study, the participants were classified in three groups: low, medium and high, based on their initial levels of self-efficacy beliefs obtained from the STEBI-B. It was found that regardless of the initial levels of self-efficacy beliefs that the participants had at the beginning of the course, the participants from all three groups reported positive changes in their self-perceptions as a science teacher and their confidence to teach. This finding concurs with the results of two studies conducted within the area of mathematics education focusing on mathematics self-efficacy. Both studies investigated mathematics self-efficacy beliefs for different groups based on initial levels of mathematics content knowledge (Newton et al. 2012; Swackhamer, et al. 2009).

Fourth, a vast majority of studies that investigated factors affecting preservice elementary science teachers’ science self-efficacy beliefs in science methods courses have utilized Bandura’s (1997) or Palmer’s (2006b) frameworks of sources of self-
efficacy (Bautista, 2011; Brand & Wilkins, 2007; Gunning & Mensah, 2011), but none of the studies focused primarily on the extent to which science content course-related factors support preservice elementary science teachers with different initial levels of self-efficacy beliefs. For this study, the idea was that the preservice elementary science teachers with different levels of self-efficacy beliefs may attend to different course aspects during their science coursework and that may affect their own perceptions of science and science teaching. The discussion around the course-related factors is further elaborated in subsequent sections.

**Discussion of the Findings**

**Development of Science Self-efficacy Beliefs**

The results of this study provided evidence that preservice teachers enrolled in the specialized content course had positive changes in their science self-efficacy beliefs. This was evident from the analyses of the STEBI-B that there were significant gains in preservice teachers’ personal science teaching efficacy (PSTE) and science teaching outcome expectancy (STOE) over the period of the content course. In addition, the participants’ responses to the interview questions strongly supported the conclusion that participants experienced positive changes in their science teacher self-images and confidence to teach at the end of the semester-long content course. The practical significance was higher for PSTE (partial $\eta^2 = .656$) as compared to STOE (partial $\eta^2 = .178$). One logical explanation for the moderate effect in STOE as compared to PSTE is that the participants had no formal classroom teaching experience and have yet to student teach. Therefore, expecting preservice teachers to fully assess how their future students will respond to their science teaching (STOE) before their student teaching experience
may be unreasonable. The higher effect in PSTE also seems logical, as participants reported that they felt that they learned the content taught in the course and they felt more comfortable teaching it.

The findings of this study regarding positive gains in self-efficacy beliefs on both scales (PSTE and STOE) are consistent with other previous studies that explored teacher self-efficacy in the context of methods courses (Bautista, 2011; Bleicher & Lindgren, 2005; Cantrell 2003; Palmer, 2006a & 2006b) and science content courses (Bergman & Morphew, 2015; Narayan & Lamp, 2010). Some studies reported mixed results suggesting gains in one of the two subscales – personal efficacy (PSTE) or outcome efficacy (STOE). For example, studies such as Cantrell et al. (2003), Tosun (2000) and Hechter (2011) found gains in PSTE scale but not in the STOE scale. Hechter (2011) asserts that developing preservice teachers’ science self-efficacy early on, before they enter into their methods coursework is critical. Findings of this study provided evidence that preservice teachers demonstrated positive shifts in their science self-efficacy beliefs in their science content course, they are more likely to arrive in their science methods courses with such increased levels of self-efficacy beliefs (Avery & Meyer, 2012; Hechter, 2011). This also has an additional advantage that such beliefs may then be carried by preservice teachers as they enter into their student teaching and future classrooms (Bautista, 2011; Gunning & Mensah, 2011).

**Science Self-efficacy and Science Conceptual Understanding**

One body of literature asserts that in-depth understanding of science content is necessary for developing confidence to teach science (Appleton, 2006; Bleicher & Lindgren, 2005; Jarrett, 1999). There is a reason to conjecture that science content
knowledge and self-efficacy beliefs are linked (Bleicher & Lindgren, 2005). In contrast to the findings from the Bleicher and Lindgren (2005), the data from this study showed no significant relationships between science conceptual understanding and science self-efficacy subscales (PSTE and STOE) on the pre-test or post-test scores. 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 ($r = 0.35$). These findings indicate that the participants who have higher gains in science conceptual understandings are more likely to develop higher self-efficacy beliefs or vice-versa.

The results, showing significant correlations between the gains in the two constructs, suggest a more complicated picture of the association between science conceptual understandings and science self-efficacy beliefs. The findings suggest that there is not necessarily a relationship between science conceptual understanding and science self-efficacy beliefs in an absolute sense, but the changes in science conceptual understanding is positively correlated with the changes in science self-efficacy beliefs. This is an interesting result showing the relationship between the process of learning science, versus science discipline knowledge itself, and the development of science self-efficacy beliefs. Another body of literature argue that having access to science disciplinary knowledge is critical to gain competence in teaching science (Leonard et al., 2011; Yilmaz-Tuzun, 2008). The data from this study did not provide any evidence to support this claim because no correlations were found between pre- or post-measures of science self-efficacy beliefs and science conceptual understandings. Interestingly, the data from this study suggests that the ways in which science learning progresses may be
related to the progress in science self-efficacy beliefs. This finding is consistent with the viewpoint in literature that mere exposure to the subject matter knowledge as in traditional sense, 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). Instead, an environment where science learning is a developmental process is promising. In the case of this study, while the quantitative data showed that the progress on science conceptual understandings correlated with the progress on self-efficacy beliefs, the qualitative data from participants’ interviews also exhibited this tendency where participants’ descriptions at several instances suggested their progress on science learning was linked to their development of confidence to teach science in their future.

Realizing that the process of development of deeper conceptual understandings and the process of increasing self-efficacy beliefs are interconnected, science educators involved in preservice science teacher preparation should pay close attention to preservice elementary teachers’ science conceptual development throughout their science coursework. One way to achieve this is through offering integrated content courses that allow science learning utilizing research-based pedagogies, such as learning cycles and 5E model as in the case of this study. Specialized content courses, such as the one in this study, have an additional advantage of a ‘depth versus breadth’ approach for better understanding of the science concepts for future elementary science instruction. Evidently, such an environment would allow increases in science conceptual understandings as well as increases in science self-efficacy beliefs, as in the case of this study. For those preservice preparation programs, where science methods courses are
offered in isolation with science content courses, perhaps there is a need to reinforce more science concepts blended within effective pedagogies. Similarly, the science content courses should incorporate appropriate evidence-based pedagogies to enhance science learning.

The study found moderate correlation between the changes in science conceptual understanding and the changes in personal science self-efficacy ($r = 0.35$). Thereby, the relationship explains a limited amount of the underlying variability. One reason may be that there are other factors/variables involved in the development of science conceptual understandings and science self-efficacy beliefs. More so, due the intricacies of the two constructs, exploring the relationship between science self-efficacy and science conceptual understandings is tricky. Recognizing that science self-efficacy beliefs are complex and malleable, perhaps the moderate positive correlation found in this study between the changes in science self-efficacy beliefs and science content understandings is encouraging. Because of the association between science self-efficacy and science conceptual understandings, it is therefore important for science educators to continue to explore others factors that mediate such processes. Researching factors that may work together to support development of science content understanding and science self-efficacy beliefs will allow course instructors to better structure their courses to support preservice elementary teachers science learning for their future teaching careers.

In contrast to the findings above, no significant correlations were found between the outcome expectancy and science conceptual understanding pre, post or between gains. In terms of outcome expectations, perhaps the case that preservice teachers enrolled in science content course have yet to experience student teaching to make
judgments on how their students may react to their teaching. The above findings are in accordance with other studies such as Bleicher and Lindgren (2005) who found no relationship between science conceptual understandings and outcome expectancy, Cantrell et al. (2003) found number of science courses to be a predictor of PSTE beliefs but not STOE beliefs, and Newton et al. (2012) found no significant relationship between mathematics content knowledge and outcome expectancy.

The findings of this study support the notion in the field that how science content is presented can support preservice teachers’ development of science conceptual understandings and science self-efficacy beliefs. The next section focuses on the discussion of factors associated with the course that resulted in positive changes in participants’ perceptions of science and science teaching.

**Factors to Facilitate Self-efficacy**

One of the primary goals of this study was to extend the knowledge base regarding the factors that support preservice elementary teachers with varied levels of self-efficacy beliefs to achieve new levels of confidence to teach science. Figure 7 presents the model, a result of grounded theory, illustrating factors effecting participants’ self-efficacy beliefs in this study. The model illustrates the factors influencing preservice elementary teachers’ science self-efficacy beliefs in the context of a specialized science content course. The four contributing factors include: science conceptual understandings, active learning experiences such as hands-on learning, teaching strategies such as learning cycle and multiple representations of the content, and instructor as a positive role model of a science teacher. Each factor makes its own unique contribution towards participants’ perceptions of science teaching and learning; together they contribute
towards positive science self-efficacy beliefs (as indicated by the arrows between factors and science self-efficacy beliefs.

![Diagram](image)

*Figure 7. Factors contributing towards self-efficacy beliefs*

In this study, the interview data suggested that the participants’ perceptions of preparedness to teach science was facilitated by deeper science conceptual understandings. The preservice elementary teachers’ responses to interview questions strongly suggested that they are more comfortable to teach science learned in the course in their future classrooms. This improved sense of science self-efficacy was particularly evident for participants from the low and medium groups who initially reported negative feelings about science and science teaching. It appeared that the participants seemed to benefit from the ways in which science concepts were presented, which they referred to be different from their previous science classes. In the case of this study, time spent on science activities, grade-appropriate science topics, and the pace at which learning progressed were important factors for preservice teachers to find science taught relevant for their future elementary instruction. Such positive active science experiences are
valuable for participants, especially low efficacious group, to develop more positive attitudes towards science and science teaching. The findings of this study supported the notion that engaging preservice teachers actively in science learning is important for preservice teachers to be able to develop appreciation for science and science teaching (Bergman & Morpew, 2015; Fencl & Scheel, 2005). Science educators involved in preparing preservice elementary teachers should place greater emphasis on selecting appropriate science activities and spending more time to help prospective teachers see science as relevant for their future science instruction.

The hands-on experiences, group-discussions, use of white-boards, and interactive computer simulations proved to be particularly beneficial for all participants. Interestingly, the participants’, especially from low and medium groups, initial levels of self-efficacy, found this approach ‘learning science by doing science’ to change their attitudes towards science. This is in accord with the literature that engaging preservice teachers’ to experience science first-hand helps preservice teachers to appreciate science (Gunning & Mensah, 2011; Leonard et al., 2011). The positive shifts in the low and medium group participants’ self-image as science teachers provided additional evidence that science and pedagogy-rich experiences could surpass their prior negative attitudes towards science and science teaching (Mulholand & Wallace, 1996; Rice & Roychoudhury, 2003). In addition, it is expected that offering opportunities for preservice teachers to experience science consistent with the ways that they are expected to teach will most likely bring positive lasting effects on elementary preservice teachers’ self-efficacy beliefs, especially for low-efficacious students as found in this study.
Another factor found to be beneficial to the development of preservice teachers’ science self-efficacy beliefs include exposure to teaching strategies that are effective for elementary science instruction. These pedagogies were helpful for participants to engage themselves in learning science in ways that are similar to how they are expected to teach in the future. This was well articulated by participants that they benefited from the learning cycle approach and multiple representations of the content and that these strategies afforded them with ideas for effective science teaching. These findings are consistent with other research studies in the field that suggest that high-quality science experiences along with effective pedagogies have potential to shape science self-efficacy beliefs (Cantrell et al., 2003; Gencer & Cakiroglu, 2007; Mulholland & Wallace, 2001). Early exposure to evidence-based instructional practices that provide preservice teachers ideas for effective science instruction is necessary to build strong foundations for future science teaching (Yoon et al., 2006; Avery & Meyer, 2012).

While one body of literature on self-efficacy beliefs claim that science methods courses is the platform where prospective teachers learn how to teach and that support their self-efficacy beliefs (Bautista, 2011; Rice & Roychoudhury; 2003). However, this study provided evidence that effective teaching strategies can be embedded within science content courses and can successfully support development of science self-efficacy beliefs. Science instructors involved with teaching preservice science content courses should structure the courses to include research-based science teaching practices that are effective to teach science. If science content courses are offered within content departments, then designing science content courses should be a collaborative effort between the science faculty and science education faculty. Such collaborations would
ensure an environment that delivers high-quality science experiences along with modeling of evidence-based science teaching practices for preservice teachers to develop science self-efficacy early on for their future teaching career.

The course instructor’s enthusiasm and positive approach towards science teaching was another strong contributor that shaped participants’ perceptions of a successful science teacher. The participants mentioned several attributes such as the course instructor’s use of multiple representations, encouraging preservice teachers to ask questions throughout the lesson, being available for students as needed, and circulating around the classroom to check their understanding. In fact, many remarked about the classroom environment to be fun and rather non-intimidating compared to some of their prior science classes. Thus, it is important to note that science instructor’s teaching practices could foster development of positive science teacher image. In the case of this study, the participants mentioned that the science classroom itself felt like a ‘model for an elementary classroom’ that they could expect for themselves in future. This finding is supported by other studies that found science methods course teachers’ behavioral patterns influenced preservice teachers’ self-efficacy beliefs and attitudes towards science teaching (Ramey-Gassert & Shroyer, 1992; Rice & Roychoudhury; 2003). Researchers in the field have alluded that teachers tend to teach the way they are taught, thus witnessing a positive role model of a science teacher could be a strong contributor towards preservice teachers’ future teaching practices. Science course instructors need to ensure that preservice teachers are provided with all supports needed for developing their confidence in science and science teaching, especially for those who come from relatively poor science backgrounds.
A Comparison with Bandura’s Sources of Self-efficacy

Among the four major sources of self-efficacy proposed by Bandura (1997) – mastery experiences, vicarious experiences, verbal persuasion and emotional arousal, researchers working in teacher education claim mastery experiences (successful classroom teaching experiences) to be the most influential in shaping preservice teachers’ self-efficacy beliefs (Buss, 2010; Cantrell et al., 2003; Gunning & Mensah, 2011). Many argue that mastery experiences such as a course coupled with field experience that allow students to practice teaching has a greater potential for developing self-efficacy beliefs (Bautista, 2011; Mulholland & Wallace, 2001). While having opportunities to teach the lesson has an advantage, others in the field put forth the question about whether courses built around other sources of self-efficacy, such as witnessing an instructor as a successful model for science teaching or experiences with ‘activities that work’, has a similar potential to enhance self-efficacy beliefs to the same extent (Palmer 2006b; Yoon et al., 2006). The findings of this study concurs with other studies that found that courses structured around constructivist approaches and modeling effective pedagogical strategies were as effective in enhancing preservice teachers’ self-efficacy beliefs (Palmer, 2006b; Bautista, 2011).

One may argue that mastery experiences, for instance planning and teaching a science lesson in school settings, has a greater potential to influence preservice teachers’ self-efficacy beliefs as compared to the other science-related experiences that may not involve teaching in a classroom. The study conducted by Palmer (2006b) addressed this issue by comparing the preservice teachers’ self-efficacy scores, after being exposed to the course that offered hands-on science experiences but no student teaching, with other
research studies that investigated self-efficacy in courses that centered on providing first-hand teaching experiences (mastery experiences). No major differences were noticed between the self-efficacy scores (pre and post) from various studies. Palmer (2006b) asserted that providing opportunities for preservice teachers to experience science learning similar to ways they are expected to teach has potential for preservice teachers as in courses that provide opportunities to teach. On similar lines of action, Table 20 provides a comparison between the findings from this study with those from other recent studies. The table shows that the raw mean post-PSTE scores of this study is only slightly lower than the scores from other studies listed. The raw mean post-STOE scores of this study is slightly lower than scores from some studies, but higher than some others in the list. This implies that the courses that provide meaningful science experiences combined with a variety of pedagogical models are effective in shaping preservice teachers’ science self-efficacy beliefs.

Table 20

*General comparison between studies on STEBI scores*

<table>
<thead>
<tr>
<th>Research Studies</th>
<th>Description about the course</th>
<th>PSTE</th>
<th>STOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantrell et al. (2003)</td>
<td>Methods and processes of science. Student teaching practicum.</td>
<td>46.33*</td>
<td>53.58*</td>
</tr>
<tr>
<td>Palmer 2006b)</td>
<td>Hands-on science experiments. No student teaching component.</td>
<td>42</td>
<td>53</td>
</tr>
<tr>
<td>Bautista (2011)</td>
<td>Inquiry-based activities, creating lesson plans, field experiences.</td>
<td>43</td>
<td>52.52</td>
</tr>
<tr>
<td><strong>This study</strong></td>
<td>Inquiry-based science experiments. No student teaching component</td>
<td>44.76</td>
<td>52</td>
</tr>
</tbody>
</table>

*Prior to and at the end of methods course
Challenges

In addition to identifying positive contributors towards participants’ self-efficacy beliefs, one unique aspect of this study was to identify challenges that continued to affect preservice teachers’ perceptions of science teaching. Recognizing that these challenges may interfere with feelings about one’s own abilities to teach science, science classes should be structured to include elements that could address these challenges. This study data showed that some of the participants from the low and medium groups continued to express concerns regarding their preparedness in science. It is not uncommon for preservice teachers to arrive in college with limited science knowledge that continue to affect their perceptions of themselves as a science teacher (Yoon et al., 2006). It is reasonable to believe that the low and medium group may have a greater need for science experiences that make explicit connections to their real life as well as future science teaching. Purposeful selection of science experiences within the science content courses can influence students’ perceptions of being able to appreciate science, as well as feeling confident to teach science (Ramey-Gassert & Schroyer, 1992; Schoon & Boone, 1998).

Other impediments to the development of participants’ confidence were from the lack of knowledge of how to teach in an elementary classroom. The content course did not intend to focus explicitly on ‘methods’ of teaching science but utilized effective pedagogical models for teaching science content such as the learning cycle and multiple representations of the content. Perhaps holding discussions on how some of these pedagogical models are successful for elementary science teaching would help preservice teachers to make connections between these experiences and future science teaching. It may also help to have preservice teachers collaborate and design at least one science
lesson on the topics learned in their science content course and practice teaching to their peers. Any experience of practicing science teaching is beneficial (Mulholand & Wallace, 2001) and may also help in smooth transitioning into the methods coursework and student teaching.

Another pressing concern among all group participants was ‘fear of failure’ in their future classrooms. Participants expressed concerns regarding failure of activities to go as planned, being able to manage student behaviors during the hands-on activities or otherwise, and to be able to respond to student queries on the science topics. Other studies have also noted similar concerns among preservice teachers who have not completed their student teaching (Brand & Wilkins, 2007; Gunning & Mensah, 2011; Settlage et al., 2009). These concerns, if not sufficiently addressed, would continue to affect their science self-efficacy beliefs that will then be carried to other stages of their teacher preparation.

Finally, although preservice teachers enriched their science conceptual understandings, many mentioned doubts on being able to retain information learned in the course by the time they arrive in their future classrooms. Of course, it was unrealistic to predict whether or not the study participants would retain their knowledge during their student teaching or in future inservice career at the time of this study. This issue, however, is important for effective science content preparation and retention and certainly needs further exploration (O’Neill & Stephenson, 2012). While this raises questions about the long-term impact of science content courses, the positioning of content courses with regard to the overall structure of the teacher preparation program should be considered. If science methods courses are the next step in the sequence,
science methods instructors should provide opportunities to reinforce the science content learned previously while teaching ‘methods’ of science teaching. One practical solution would be to offer ‘integrated’ methods and content courses that prioritize specific needs of prospective elementary science teachers. Such integrated science courses should also provide opportunities for preservice teachers to practice teaching in some capacity, if not extensive, instead of having them wait until their student teaching practicum.

**Limitations**

One of the limitations of this study is the degree to which one could control various internal and external variables that may affect changes in conceptual understanding and self-efficacy beliefs of preservice teachers. For example, the study explored the relationship between pre-existing science self-efficacy beliefs and preconceptions about targeted science topics within the research context; however, there are other factors that are outside the research context but yet may impact this relationship. For example, information on background variables such as participants’ high school science grades, high school context-rural vs. urban and standardized test scores (ACT scores) for the science tests taken prior to the involvement in preservice teacher program are beyond the scope of this study. Similarly, demographic variables such as participants’ gender, age, ethnicity etc. might have contributed towards participants’ existing science self-efficacy beliefs, but were not included as part of the investigation for this study.

Secondly, efforts were made to account for all the interactions that took place within the research setting through careful observations of the class; however, it is expected that some information within the context may be overlooked. More so, considering the class size (~30) there is no way to keep record of the all social
interactions and meaningful discussions that were taking place inside the classroom at a given time. For instance, some activities demanded students to work at different stations placed inside and outside the classroom area, increasing the impracticality of comprehensive observations. Additionally, the preservice teachers often met outside the class for completing assignments in small study groups, discussing homework tasks, and making project presentations, which were not tracked by the researcher. However, in an effort to account for this limitation, interviews were carefully designed to gather as much information about the contributing factors regarding changes in science self-efficacy beliefs. Also, it can be speculated that the longitudinal nature of the study provided robustness and may have helped reduce the effect of superfluous variables.

Additionally, the results of this study are situation-specific, which is specialized elementary physical science content course that served as the context of the study. Hence, the findings of the study are limited to preservice elementary teachers’ conceptual understanding of targeted physical science topics taught in this content course. It is possible that the factors that influenced self-efficacy may not be the same for other populations of preservice teachers such as in middle or secondary level or in courses offered in other content areas. Thus, care should be taken when generalizing to other settings, or other science discipline areas.

**Implications of the Study**

The results of this study provided evidence that ways in which science content knowledge was presented in the course provided valuable support for preservice teachers to enhance their science self-efficacy beliefs. Like previous research, the findings of this study also supported the notion that content-rich experiences along with the modeled
teaching strategies contributed significantly towards students’ understanding of the science content and overall confidence to teach science. This study has important implications for preservice elementary science teacher preparation and science educators involved in preparing future elementary teachers and possibilities for further research.

**Implications for Science Teacher Preparation Program**

The study has major implications for science teacher preparation programs and courses at the college level. First, developing courses that integrate content and pedagogy where preservice teachers’ self-efficacy are nurtured through (1) engagement in science practices relevant to their future teaching (2) exposure to effective models of teaching science. In the case of this study, preservice teachers’ science self-efficacy beliefs were enhanced by learning science content through pedagogical approaches such as learning cycle explorations and multiple representation of the content. Such integrated content-pedagogy-based courses offer unique advantages over traditional content courses providing opportunities to engage students in science learning along with exposure to effective science teaching practices. However, developing content-pedagogy integrated courses could be a challenging task, but is possible through collaborations between science and science education faculty where both sets can bring their expertise into such an effort. Perhaps, holding a discussion at the administrative level is needed for providing necessary supports for faculty to plan, develop and teach integrated courses (Bergman & Morphew, 2015). Other issues associated with teaching integrated courses that also need attention might be the resources, faculty training, timing and scheduling of integrated courses, and incentives involved with it.
Second, in addition to the structure and organization, close attention is needed on the placement of such courses within the overall teacher preparation program. Such courses should be accompanied with student teaching component or field experiences should be followed immediately after these courses. There are merits to such kind of placement while simultaneously enrolled in content courses. Effective field experiences help address some of the concerns and apprehensions preservice teachers have about their ability to teach science (Mulholland & Wallace; 2001, Gencer & Cakiroglu, 2007). In the case of this study, several participants expressed concerns about how the science activities learned would work in elementary classrooms or they may forget concepts or examples learned in the course. Therefore, it can be expected that having first-hand teaching opportunities right away, while preservice teachers are still in their content courses, would help retain content learned for longer periods of time and make better connections to future teaching rather than waiting for science practicum experiences to come later on.

**Implications for Practice**

Preservice teachers arrive at college holding varied beliefs about science and science teaching originating from prior high school science experiences. Considering that not all preservice teachers have prior experiences that are “positive”, integrated courses should include as many opportunities to make science relevant to their real-world. Science educators working in the area of preservice teacher education must create new experiences that allow preservice teachers, especially those who hold negative attitudes towards science, to change their attitudes towards science and science teaching. As in this study, the course instructor created an environment that fostered development of science
conceptual understanding and positive attitudes towards science. In particular, the low group participants felt welcomed to ask questions and felt that the instructor cared for their learning. As the findings suggest, the course instructor’s enthusiasm and encouragement can bring positive changes in low efficacious participants’ image of a science teacher.

One may argue that expecting science faculty to teach using research-based pedagogies that are prevalent in science education field could be a bit of a stretch. One may ask: Are science faculty, who serve as instructors to science content courses that preservice teachers take, well equipped with the knowledge of research-based instructional strategies to be able to teach science content utilizing these effective pedagogies? One possible solution is to provide necessary support to both science and science education faculty in designing integrated science content courses. This may include providing professional development opportunities for faculty, particularly science faculty, involved in teacher preparation. Such professional development should explicitly focus on knowledge of research-based instructional strategies that are proven effective, curriculum that support preservice teachers’ content and pedagogical needs, and how to design science activities that engage preservice teachers in meaningful experiences to shape their science self-efficacy beliefs.

In this study, preservice teachers seemed to benefit from the use of learning cycle and multiple representations of the content, which provided effective models for future teaching. Such elements must be included in courses for preservice teachers, especially the low and medium efficacious group’ to see successful models of science teaching and thus, enhance their repertoire of ‘teaching strategies that work’. Having a close look into
the course elements that influence students with different initial levels of self-efficacy beliefs, science educators could include elements within science content courses to potentially support low efficacious students. Because self-efficacy is shaped by experiences teachers gain during their preservice program, there is reason to believe that educators should continue to make efforts to extend their support at all stages of science teacher preparation.

**Implications for Future Research**

The preservice teachers’ science self-efficacy beliefs significantly changed at the end of the content course. However, more research is needed to understand its long-lasting effect – whether high levels of self-efficacy beliefs are maintained throughout the preservice program. Studies should continue to take a holistic look at the teacher preparation program – how can preservice teachers be supported at various stages of the teacher preparation program (Hechter, 2011).

Another exciting area of research would be to explore how gains in self-efficacy translates into classroom practices. Improved self-efficacy beliefs are not a panacea to effective future science teaching. It would be interesting to follow preservice teachers into their classrooms to understand how different sources of self-efficacy play a role in beginning teachers’ classroom practices. Studies should continue to explore factors that influence preservice teachers’ science self-efficacy beliefs – perhaps looking into in-school and out-of school factors and how they interplay could prove beneficial. Such longitudinal studies would also help design preservice courses better for preparing next generation of high-quality science teachers (Cakiroglu, Capa-Aydin, & Hoy, 2011).
Possibilities for further research could also include studies that continue to explore links between science self-efficacy beliefs and science content knowledge. The role of content knowledge in influencing self-efficacy beliefs has been under speculation for quite a long-time, thus more studies are needed for investigating the relationship further. While this study found evidence that gains in preservice elementary teachers’ science self-efficacy beliefs and gains in science content knowledge are correlated, it would be interesting to see if this relationship holds true in other contexts such as with preservice middle or secondary science teachers. Furthermore, it would be interesting to examine the relationship between the two constructs in other science discipline areas—such as biology or chemistry content courses that the preservice teachers might enroll in.

**Conclusion**

When we talk about today’s science education in elementary settings, as a field we often focus on augmenting the pool of high-quality science teachers to further engage elementary learners in practices that support student learning as well as develop their interest in science. Such an outlook requires a significant amount of groundwork at the elementary teacher preparation level. The idea is to provide ample opportunities for preservice teachers to develop strong understanding of science through pedagogical approaches for them to be able to feel confident for future science teaching. Shaping preservice teachers’ self-efficacy beliefs during their college coursework is critical for their future science teaching. This further requires more efforts to reform teacher preparation coursework to develop more integrated courses that blend content and pedagogy together.
This study investigated how elementary preservice teachers’ science self-efficacy beliefs change in a content course, and factors associated with such changes. It was found that content-rich environment supported with effective teaching pedagogies resulted in positive self-image, attitudes and confidence to teach science. Further investigation was conducted to understand the relationship between elementary preservice teachers’ science conceptual understandings and science self-efficacy beliefs. Findings suggest that development of science conceptual understandings are more likely to improve gains in science self-efficacy beliefs.

While continuous research is needed to understand the development of self-efficacy trajectories better, it is necessary to follow teachers into their classroom to inform better design of teacher preparation programs. Planning and conducting such initiatives involving teacher preparation should not be the responsibility of science educators alone. Researchers and educators working in science education as well as faculty from science departments should work together towards achieving the ultimate goal of scientific literacy for all.
Appendix A: STEBI-B

By (Enochs & Riggs, 1990, modified Bleicher, 2004)

Please circle your choices for each statement on the sheet that best matches the degree to which you agree with each statement below.

5 = STRONGLY AGREE
4 = AGREE
3 = UNCERTAIN
2 = DISAGREE
1 = STRONGLY DISAGREE

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>When a student does better than usual in science, it is often because the teacher exerted a little extra effort.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>I will continually find better ways to teach science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>Even if I try very hard, I will not teach science as well as I will most subjects.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td>I know the steps necessary to teach science concepts effectively.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>6.</td>
<td>I will not be very effective in monitoring science experiments.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>7.</td>
<td>If students are underachieving in science, it is most likely due to ineffective science teaching.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>8.</td>
<td>I will generally teach science ineffectively.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>9.</td>
<td>The inadequacy of a student’s science background can be overcome by good teaching.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>10.</td>
<td>The low science achievement of students cannot generally be blamed on their teachers.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>11.</td>
<td>When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>12.</td>
<td>I understand science concepts well enough to be effective in teaching elementary science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>13.</td>
<td>Increased effort in science teaching produces little change in students’ science achievement.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>14.</td>
<td>The teacher is generally responsible for the achievement of students in science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
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</table>
### Appendix A (Continued)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>SA</th>
<th>A</th>
<th>UN</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.</td>
<td>Students’ achievement in science is directly related to their teacher’s effectiveness in science teaching.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>16.</td>
<td>If parents comment that their child is showing more interest in science, it is probably due to the child’s teacher.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>17.</td>
<td>I will find it difficult to explain to students why science experiments work.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>18.</td>
<td>I will typically be able to answer students’ science questions.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>19.</td>
<td>I wonder if I will have the necessary skills to teach science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>20.</td>
<td>Given a choice, I will not invite the principal to evaluate my science teaching.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>21.</td>
<td>When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>22.</td>
<td>When teaching science, I will usually welcome student questions.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>23.</td>
<td>I do not know what to do to turn students on to science.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
### Appendix B: Physical Science Concepts

<table>
<thead>
<tr>
<th>Topic</th>
<th>Concept (Sub-concept)</th>
</tr>
</thead>
</table>
| **Electricity and Magnetism** | **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  
(3) Understand the conservation of charge in a variety of circuits  
(4) Understand how switch works (contact points)  
(5) Understand how switch can be used in the circuit to turn bulb on and off  

**Series circuits:**  
(1) Recognize how series circuits are represented  
(2) Understand and compare the brightness and current flowing through the one bulb and multiple bulb circuits  
(3) Understand and compare the voltage in one bulb and multiple bulb circuits  
(4) Understand and compare the resistance of one bulb and multiple bulb circuits  

**Parallel circuits:**  
(1) Recognize how parallel circuits are represented  
(2) Understand and compare the brightness and current flowing through one bulb and multiple bulb circuits  
(3) Understand and compare the voltage in one bulb and multiple bulb circuits  
(4) Understand and compare the resistance of one bulb and multiple bulb circuits  

**Equivalent circuits:**  
(1) Compare and contrast between series and parallel circuits  

**Magnetic field of a magnet:**  
(1) Understand the poles of a magnet (north and south)  
(2) Understand magnetic field lines of force around the magnet and its relation to magnetic strength  
(3) Understand the various properties of magnetic field lines of force (imaginary, north to south, do not cross each other)  

**Earth's Magnetic Field:**  
(1) Understand how Earth's Magnetic field interacts with bar magnet  
(2) Understand the causes of Earth's Magnetic field  

<table>
<thead>
<tr>
<th>Topic</th>
<th>Concept (Sub-concept)</th>
</tr>
</thead>
</table>
| **Force and Motion**   | **Force Concept:**  
(1) Understand variety of forces (push or pull or both) and their effects  
(2) Understand Earth's gravitational field and how force of gravity acts on objects  
(3) Understand the concept of Inertia of rest and motion  
(4) Understand the relationship between weight and mass  

**Uniform Motion and Motion Diagrams:**  
(1) Analyze change in position and distance with time  
(2) Understand pictorial representation and interpretation of uniform motion  
(3) Understand relation between speed-distance-time
Appendix C: Selection of items based on science concepts and assessment goals

<table>
<thead>
<tr>
<th>Topic</th>
<th>Concept (sub-concept)</th>
<th>Assessment Goals</th>
<th>Item</th>
<th>Instrument</th>
</tr>
</thead>
</table>
| **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  
(3) Understand the conservation of charge in a variety of circuits  
(4) Understand how switch works (contact points)  
(5) Understand how switch can be used in the circuit to turn bulb on and off | Understand and apply the concept of conservation of charge in a light bulb and other circuits | Q 10  | DIRECT 1.2 |
|                  |                                                                                                                                                                                                                      | Understand and apply the knowledge of how a bulb works (two-contact points) in a complete circuit | Q 8   | DIRECT 1.2 |
|                  |                                                                                                                                                                                                                      | Apply the knowledge of how switch is used to open or close a circuit or in a single path. | Q 18  | DIRECT 1.2 |
| **Series circuits:** | (1) Recognize how series circuits are represented  
(2) Understand and compare the brightness and current flowing through the one bulb and multiple bulb circuits  
(3) Understand and compare the voltage in one bulb and multiple bulb circuits  
(4) Understand and compare the resistance of one bulb and multiple bulb circuits | Interpret diagrams of a variety of circuits including series, parallel and/or combination of both | Q 4, Q 11 | DIRECT 1.2 |
| **Parallel circuits:** | (1) Recognize how parallel circuits are represented  
(2) Understand and compare the brightness and current flowing through the one bulb and multiple bulb circuits | Apply the concept of resistance in series and/or parallel circuits to determine the brightness of bulbs in these circuits | Q 14, 18 | DIRECT 1.2 |
<table>
<thead>
<tr>
<th>Topic</th>
<th>Details</th>
<th>Questions</th>
<th>Direct 1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent circuits:</td>
<td>(1) Compare and contrast between series and parallel circuits</td>
<td>Q 5</td>
<td>DIRECT 1.0</td>
</tr>
<tr>
<td></td>
<td>APPLY THE CONCEPT OF RESISTANCE TO ANALYZE RESISTANCE IN SERIES AND/OR PARALLEL CIRCUITS</td>
<td>Q 6</td>
<td>DIRECT 1.2</td>
</tr>
<tr>
<td></td>
<td>APPELY THE CONCEPT OF VOLTAGE, RESISTANCE AND/OR CURRENT FLOW IN THE CIRCUIT TO ANALYZE THE BRIGHTNESS OF A BULB IN VARIOUS CIRCUITS (SERIES AND/OR PARALLEL)</td>
<td>Q12, 17</td>
<td>DIRECT 1.0</td>
</tr>
<tr>
<td></td>
<td>APPLY THE CONCEPT OF CONSERVATION OF CURRENT (CONSERVATION OF FLOW OF CHARGES) TO ANALYZE CURRENT BETWEEN TWO POINTS IN A CIRCUIT</td>
<td>Q 7</td>
<td>DIRECT 1.2</td>
</tr>
<tr>
<td>Magnetism</td>
<td>Magnetic field of a magnets:</td>
<td>Q 21</td>
<td>My PD Indexer tool</td>
</tr>
<tr>
<td></td>
<td>(1) Understand the poles of a magnet (north and south)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Understand magnetic field lines of force around the magnet and its relation to magnetic strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) Understand the various properties of magnetic field lines of force (imaginary, north to south, do not cross each other)</td>
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<td></td>
<td>Earth's Magnetic Field:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1) Understand how Earth's Magnetic field interacts with bar magnet</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Understand the causes of Earth's Magnetic field</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Force and Motion | Force Concept:  
(1) Understand variety of forces (push or pull or both) and their effects.  
(2) Understand Earth's gravitational field and how force of gravity acts on objects.  
(3) Understand the concept of inertia of rest and motion  
(4) Understand the relationship between weight and mass | Analyze pair of forces (agent and receiver) in given scenario/real world examples | Q 23, 24 | My PD Indexer tool  
FCI | Apply the concept of gravity on objects (in the given example) | Q 23, 24, 26 | My PD Indexer tool  
FCI | Apply the concept of balanced and/or unbalanced forces in given scenarios | Q 29 | FCI | Apply the concept of equal and opposite forces to various scenarios/examples (e.g., spring scales and relate it to the concept of mass and weight) | Q 26 | My PD Indexer tool  
FCI | Uniform Motion and Motion Diagrams:  
(1) Analyze change in position and distance with time  
(2) Understand pictorial representation and interpretation of uniform motion  
(3) Understand relation between speed-distance-time | Interpret motion diagrams to analyze and compare speed of moving objects at a given instant | Q 27 | FCI |
### Question

1. Which circuit or circuits below represent a circuit consisting of two light bulbs in parallel with a battery?
   - (A) Circuit 1
   - (B) Circuit 2
   - (C) Circuit 3
   - (D) Circuit 1 and 2
   - (E) Circuit 1, 2 and 4

   ![Circuits](image)

   **Goal:** Interpret diagrams of a variety of circuits including series, parallel and/or combination of both.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

   **Other Comments:**

2. Compare the resistance of branch 1 with that of branch 2. A branch is a section of a circuit. Which has the least resistance?
   - (A) Branch 1
   - (B) Branch 2
   - (C) Neither, they are the same

   ![Branches](image)

   **Goal:** Apply the concept of resistance to analyze resistance in series and/or parallel circuits.

<table>
<thead>
<tr>
<th>Agree</th>
<th>Disagree</th>
</tr>
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<tbody>
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</tbody>
</table>

   **Other Comments:**

3. Compare the brightness of the bulb in circuit 1 with that in circuit 2. Which bulb is BRIGHTER?
   - (A) Bulb in circuit 1 because two batteries in series provide less voltage
   - (B) Bulb in circuit 1 because two batteries in series provide more voltage

   **Goal:** Apply the concept of voltage, resistance and/or current flow in the circuit to analyze the brightness of a bulb in various circuits (series and/or parallel).
(C) Bulb in circuit 2 because two batteries in parallel provide less voltage
(D) Bulb in circuit 2 because two batteries in parallel provide more voltage
(E) Neither, they are the same

4. Compare the current at point 1 with the current at point 2. At which point is the current LARGEST?
   (A) Point 1
   (B) Point 2
   (C) Neither, they are the same. Current travels in one direction around the circuit.
   (D) Neither, they are the same. Currents travel in two directions around the circuit.

**Goal:** Apply the concept of conservation of current (conservation of flow of charges) to analyze current between two points in a circuit.
Appendix E: Item Analysis

Item analysis for the Physical Science Concept Test-Version A (N=110)

<table>
<thead>
<tr>
<th>Item</th>
<th>1D FIFA</th>
<th>FACILITY</th>
<th>Point-Biserial Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0.36</td>
<td>0.08</td>
<td>0.29</td>
</tr>
<tr>
<td>2.</td>
<td>0.38</td>
<td>0.58</td>
<td>0.36</td>
</tr>
<tr>
<td>3.</td>
<td>0.33</td>
<td>0.44</td>
<td>0.40</td>
</tr>
<tr>
<td>4.</td>
<td>0.27</td>
<td>0.38</td>
<td>0.32</td>
</tr>
<tr>
<td>5.</td>
<td>0.65</td>
<td>0.48</td>
<td>0.45</td>
</tr>
<tr>
<td>6.</td>
<td>0.43</td>
<td>0.04</td>
<td>0.36</td>
</tr>
<tr>
<td>7.</td>
<td>0.25</td>
<td>0.55</td>
<td>0.27</td>
</tr>
<tr>
<td>8.</td>
<td>0.22</td>
<td>0.39</td>
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<tr>
<td>9.</td>
<td>0.52</td>
<td>0.36</td>
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<tr>
<td>10.</td>
<td>0.38</td>
<td>0.65</td>
<td>0.32</td>
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<tr>
<td>11.</td>
<td>0.37</td>
<td>0.29</td>
<td>0.33</td>
</tr>
<tr>
<td>12.</td>
<td>0.19</td>
<td>0.26</td>
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<tr>
<td>13.</td>
<td>0.27</td>
<td>0.50</td>
<td>0.41</td>
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<tr>
<td>14.</td>
<td>0.76</td>
<td>0.65</td>
<td>0.54</td>
</tr>
<tr>
<td>15.</td>
<td>0.15</td>
<td>0.55</td>
<td>0.27</td>
</tr>
<tr>
<td>16.</td>
<td>0.27</td>
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<td>0.18</td>
</tr>
<tr>
<td>17.</td>
<td>0.27</td>
<td>0.54</td>
<td>0.24</td>
</tr>
<tr>
<td>18.</td>
<td>0.44</td>
<td>0.22</td>
<td>0.41</td>
</tr>
<tr>
<td>19.</td>
<td>0.44</td>
<td>0.48</td>
<td>0.33</td>
</tr>
<tr>
<td>20.</td>
<td>0.24</td>
<td>0.56</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Participant Consent Form

I would like to invite you to participate by taking the physical science content test. This is part of the bigger study focusing on understanding the relationship between preservice teachers’ science conceptual understanding and science self-efficacy beliefs. Your participation in this science content test is of great importance for the research study.

You must be at least 18 years of age to be eligible to participate in the study. Your participation in this study is completely on voluntary basis. Your course grades will not be affected by your decision to participate in the study. Only the members of our research team will use test scores to conduct statistical analysis on the data from participants’ response on this test. All individual scores will remain strictly confidential.

The entire test will take 20-25 minutes or less to complete. If you have any questions regarding the test or the research study, please feel free to contact Deepika Menon at dm2qc@mail.missouri.edu or at (573) 529-4707.

If you have any questions about your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact the Institutional Review Board at (573) 882-9585. The Campus IRB oversees all research activities involving human subjects at the University of Missouri.

CONSENT

I have read the information presented above and have had an opportunity to ask questions and receive answers pertaining to this project.

I hereby agree to participate in this research study. I am aware that my participation is voluntary and that I am free to withdraw participation at any time without any penalties to myself.

Signed: _______________________________ Date: _____________________________
Appendix F: (Continued)

Physical Science Content Test

Instructions
Wait until you are told to begin, then turn to the next page and begin working. Answer each question as accurately as you can. There is only one correct answer for each item. Feel free to use a scratch paper if you wish.

Use a #2 pencil to record your answers on the Scantron sheet, but please do not write in the test booklet.

There are two sections to complete: (1) Electricity and Magnetism (2) Force and Motion. You will have approximately 35 minutes to complete the test. If you finish early, check your work before handing in the answer sheet.

Additional comments about the test
All light bulbs, resistors, and batteries are identical unless you are told otherwise. The battery is ideal, that is to say, the internal resistance of the battery is negligible. In addition, the wires have negligible resistance. Below is a key to the symbols used on this test. Study them carefully before you begin the test.

![Symbol Key]

Batteries  Light Bulbs  Resistor  Switches
Appendix F: (Continued)

ELECTRICITY & MAGNETISM

1. Which circuit or circuits below represent a circuit consisting of two light bulbs in parallel with a battery?

(A) Circuit 1
(B) Circuit 2
(C) Circuit 3
(D) Circuit 1 and 2
(E) Circuit 1, 2 and 4

2. Compare the brightness of the bulb in circuit 1 with that in circuit 2. Which bulb is BRIGHTER?

(A) Bulb in circuit 1 because two batteries in series provide less voltage
(B) Bulb in circuit 1 because two batteries in series provide more voltage
(C) Bulb in circuit 2 because two batteries in parallel provide less voltage
(D) Bulb in circuit 2 because two batteries in parallel provide more voltage
(E) Neither, they are the same

3. Compare the current at point 1 with the current at point 2. At which point is the current LARGEST?

(A) Point 1
(B) Point 2
(C) Neither, they are the same. Current travels in one direction around the circuit.
(D) Neither, they are the same. Currents travel in two directions around the circuit.

4. 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

Circuit 1
Circuit 2
Circuit 3
Circuit 4
5. Which schematic diagram best represents the realistic circuit shown below?

(A) Circuit 1  
(B) Circuit 2  
(C) Circuit 3  
(D) Circuit 4  
(E) None of the above

6. Compare the brightness of bulb A in circuit 1 with bulb A in circuit 2. Which bulb is dimmer?

(A) Bulb A in circuit 1  
(B) Bulb A in circuit 2  
(C) Neither, they are the same

7. Compare the brightness of bulb A in circuit 1 with bulb A in circuit 2. Which bulb is brighter?

(A) Bulb A in circuit 1  
(B) Bulb A in circuit 2  
(C) Neither, they are the same
8. If you increase the resistance C, what happens to the brightness of bulbs A and B?

(A) A stays the same, B dims  
(B) A dims, B stays the same  
(C) A and B increase  
(D) A and B decrease  
(E) A and B remain the same

9. A student places a bar magnet on a smooth surface containing iron fillings. The fillings arrange themselves according to the diagram.

The student’s observation allows the following statement to be made. Which of the following statements do you agree with?

(A) The greater the density of the field lines, the greater the repulsion from the pole to each pole of a similar bar magnet.  
(B) Magnets are surrounded by magnetic fields that are constant in strength but vary in direction.  
(C) Magnets are surrounded by imaginary lines of force that exert force to orient the filings along the field lines in a definite pattern.  
(D) The greater the density of the field lines between the poles, the greater the attraction of almost all of the metals in the Periodic Table to the magnet.
10. You observe a pile of books sitting on a table while shopping at a local store. (The book pile is illustrated in the diagram.) A friend comments about the forces on the books.

Which of the comments are correct?

(A) 4 and 5  
(B) 2 and 6  
(C) 6 and 7  
(D) 1 and 3

11. The figure below shows a boy swinging on a rope, starting at a point higher than A. Consider the following distinct forces:
1. A downward force of gravity.  
2. A force exerted by the rope pointing from A to O.  
3. A force in the direction of the boy’s motion.  
4. A force pointing from O to A.

Which of the above forces is (are) acting on the boy when he is at position A?

(A) 1 only.  
(B) 1 and 2.  
(C) 1 and 3.  
(D) 1, 2, and 3.  
(E) 1, 3, and 4.

12. Two students hooked a finger in the ring ends of two spring scales and pulled on them while hooked together in opposite directions. The students found:

1. Equal and opposite pair of forces acted only on the spring scale on the right.  
2. Equal and opposite pair of forces acted only on the spring scale on the left.  
3. When the two students pulled, the Newton forces read on the scales were identical.
4. The two students are able to pull so that the Newton forces read on the scales were different.
5. Two equal forces acted on different objects.
6. One force acted and then the other force reacted.

Which of the comments are correct?

(A) 2 and 6  
(B) 1 and 6  
(C) 3 and 5  
(D) Only 4

13. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.

Do the blocks ever have the same speed?

(A) No.  
(B) Yes, at instant 2.  
(C) Yes, at instant 5.  
(D) Yes, at instants 2 and 5.  
(E) Yes, at some time during the interval 3 to 4.

14. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move.

During the push and while the students are still touching one another:

(A) neither student exerts a force on the other.  
(B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".  
(C) each student exerts a force on the other, but "b" exerts the larger force.  
(D) each student exerts a force on the other, but "a" exerts the larger force.  
(E) each student exerts the same amount of force on the other.

15. An empty office chair is at rest on a floor. Consider the following forces:

1. A downward force of gravity.  
2. An upward force exerted by the floor.
3. A net downward force exerted by the air. Which of the forces is (are) acting on the office chair?

(A) 1 only.
(B) 1 and 2.
(C) 2 and 3.
(D) 1, 2, and 3.
(E) none of the forces. (Since the chair is at rest there are no forces acting upon it.)

Appendix G: Item Statistics

Reliability Statistics for Physical Science Concept Test Version B

Cronbach’s Alpha (0.67)

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<th>Item</th>
<th>Corrected Item-Total Correlation</th>
<th>Cronbach’s Alpha</th>
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<td>.655</td>
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<tr>
<td>2.</td>
<td>.046</td>
<td>.680</td>
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<td>3.</td>
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<td>.653</td>
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<tr>
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Appendix H: Interview questions (Part 1)

1. Do you see yourself as a science teacher?

2. What motivates you to be a science teacher?

3. Did you take any science classes prior to entering college? Please summarize your experiences from those classes?
4. Did you take any science classes before taking this physics content course? Please tell the experiences from those science classes?

5. Have you taught science before? If so, summarize your teaching experiences?

6. Summarize your elementary science experiences?

7. Given a choice to rate your level of confidence to teach science on a scale of 1 to 5, 1 being very low confidence and 5 being very high confidence, how would you rate yourself? Explain why you selected a particular level?

8. Given a choice to rate your level of physical science content knowledge on scale of 1 to 5, 1 as very little knowledge and 5 as very high knowledge, how would you rate yourself? Explain why selected a particular level?

9. How effective do you think you will be teaching physical science to children? 1 as very less effective and 5 as least effective, how would you rate yourself? Explain why you selected a particular level?

10. Do you think your teaching will enhance students’ knowledge or make a difference in student achievement? Explain?

Appendix I: Interview questions (Part 2)

1. Do you see yourself as a science teacher? Has your view of yourself as a science teacher changed? How? Is this view of yourself one you like? Why? Why not?

2. Do you think your beliefs about science have changed by taking this physics course? How?
3. Describe your experiences in this physics content course that have influenced your beliefs about science? Give an example of something you used to think about science that has changed now?

4. What aspects of the course (Example: lectures, teaching models, classroom activities (specify), explanations, assessments etc.) influenced your present beliefs about science? You may describe specific incidents that happened within the course if you like.

5. Do you think your beliefs about science teaching have changed by taking this physics course? How is this change related to this course? Is this change in your beliefs something that you like? Why? Why not?

6. Describe your experiences in this physics content course that have influenced your beliefs and confidence to teach science? You may describe specific incidents that happened within the course if you like or you may describe something about how the course was taught that helped you visualize a new way to teach.

7. What aspects of the course do you think (Example: lectures, teaching models, classroom activities (specify), explanations, assessments etc.) contributed to your change in beliefs about science teaching? For example, was there something about the way your teacher interacted with the class or with you that contributed to your changed beliefs?

8. How confident do you feel prepared to teach the physical science content learned in the course? Rate your confidence on a scale of 1 to 5, 1 being very low confidence and 5 being very high confidence, how would you rate yourself? Explain why you selected a particular level? What makes you feel confident that you can teach science? What makes you question your ability to teach science?

9. Given a choice to rate your physical science content knowledge on a scale of 1 to 5, 1 being very low confidence and 5 being very high confidence in the content knowledge, how would you rate yourself? Explain why you selected a particular level?

10. Did this physics content course prepare you for the challenges you may face when teaching science? In what ways do you think the course prepared you? In what ways do you think the course did not prepare you?

11. How effective do you think you will be teaching physical science to children on a scale of 1 through 5, 1 being not very effective and 5 being highly effective? Explain why you selected a particular level.

12. Do you think your students will be able to learn physics as a consequence of your teaching? Why do you think so?
13. Do you think your science teaching will make a difference in your students' achievement? Why do you think so?

14. What more could this physics content class have done to better prepare you to effectively teach science?

REFERENCES


International conference of the National Association for Research in Science Teaching, Oak Brook, IL.


Ritter, J. M., Boone, W. J., & Rubba, P. A. (2002). Extension of the self-efficacy beliefs about equitable science teaching and learning instruments to include learning support and gifted and talented students. Paper presented at the annual meeting of the Association for the Education of Teachers in Science, Charlotte, NC.


VITA

Deepika Menon was born on May 18, 1979 to Gopal Krishan and Sarojini Menon of Punjab, India. Deepika has her Bachelor of Science degree (physics honors) and Bachelor of Education (Science Education) from Regional Institute of Education, Bhubaneswar, India. Deepika got her Master of Science degree in Physics from D.A.V College, Jalandhar, India. Deepika then taught high school physics at the Shiv Jyoti Public School, Punjab, India for five years. While teaching, Deepika earned her Masters of Education (Science Education) degree from Punjab University, India.

Deepika married Sunil Singh, in 2009, and they have a son, Rayan Singh. They will be residing in Towson, Maryland as Deepika has accepted a tenure-track assistant professor in science education in the department of Physics, Astronomy and Geosciences at Towson, University in Towson, MD. Deepika is looking forward to continue her passion to promote effective science teacher education, especially learning and teaching of physics.